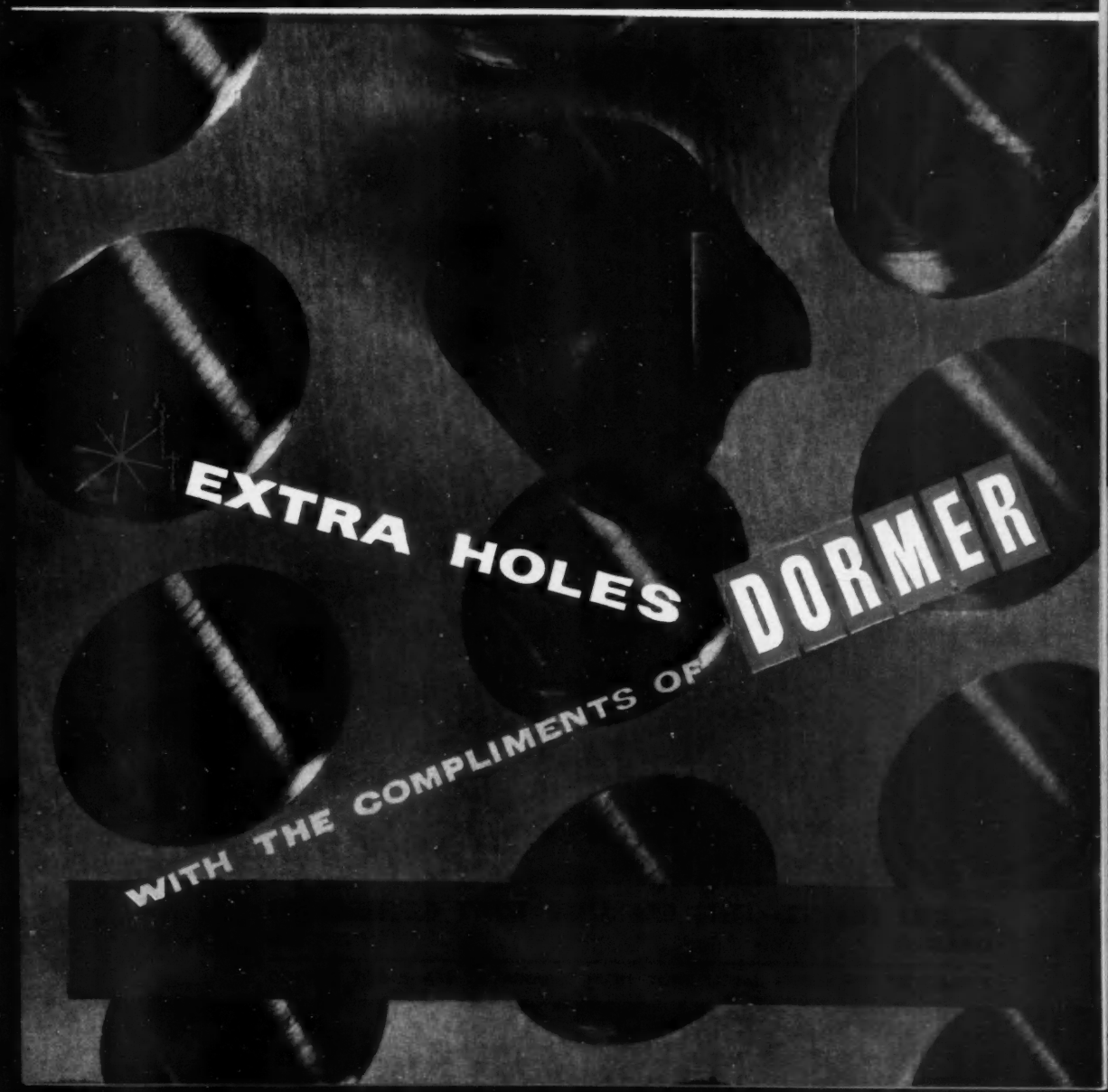
The
ENGINEERS' DIGEST

A World Review of
DESIGN & PRODUCTION · RESEARCH & DEVELOPMENT

VOL. XXII No. 9 SEPTEMBER, 1961



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The MINIDIGEST

A new **powder-metallurgy technique for making electric-motor armatures** takes advantage of the controlled expansion that can be achieved by sintering a bronze powder. In this technique (reported briefly in *Materials in Design Engineering* for June 1961), the core of the armature is pressed from the pre-alloyed bronze powder, and an outer ring is pressed from steel powder and sintered. The core and ring are then internested, and the core is sintered, the resulting expansion firmly bonding the assembly. Finally, the outer ring is machined off to produce the armature with alternating magnetic and non-magnetic sections. It is stated that this technique reduces costs by as much as 72% by eliminating the machining and staking or peening operations normally used in conventional methods of armature construction. Moreover, it is expected to provide greater reliability, as staked segments are more likely to break loose at high rotational speeds. The possibility also exists of making the inner core of a ferromagnetic material and the outer ring of brass, in which case controlled shrinkage of the brass would be used to obtain the bond between the core and ring.

* * *

According to an article in *The Journal of the Institute of Electrical Communication Engineers of Japan* for March 1961, a **new dual-polarization parabolic antenna for broad-band microwave relay systems** has been developed and is being installed for the radio link between Tokyo and Osaka. In this antenna, which can carry more than 1800 telephone channels, the primary feed horn has a symmetrical hybrid circuit for dual polarization and a phase-shifter made of five metallic parts for circular polarization. This arrangement reduces reflection from the mirror surface and minimizes the effects of snow, ice, or rain-drops on the aperture of the horn. Other advantages of this antenna over antennae of conventional design are claimed to be its small weight, its greatly reduced windage area, and its ease of installation.

* * *

A new class of **nitrile-containing silicone fluids,** with such properties as solvent resistance, limited electrical conductivity, and high dielectric constant, has been developed in the U.S.A. by General Electric. These nitrile-silicone fluids, which are similar to dimethyl-silicone fluids in that they have a low surface tension,

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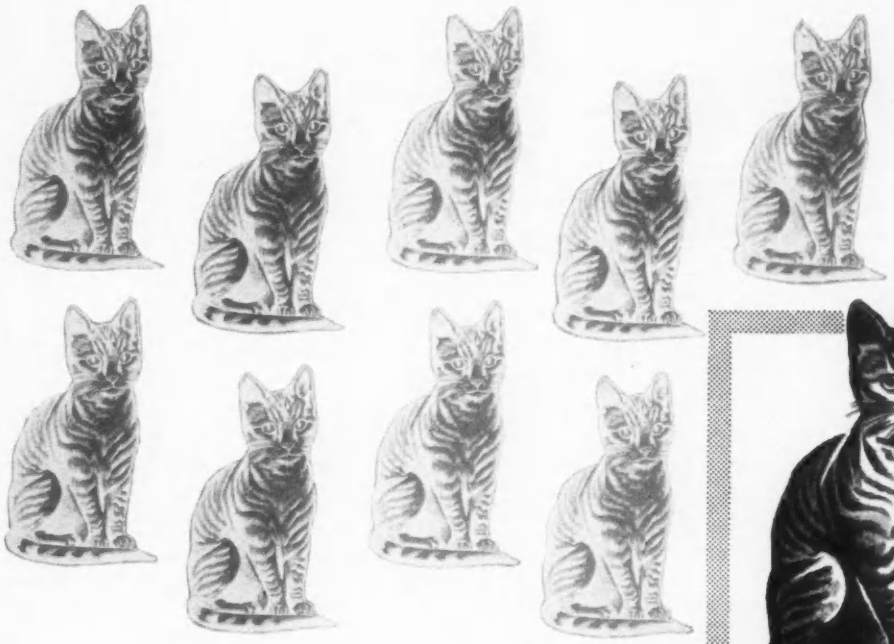

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The MINIDIGEST

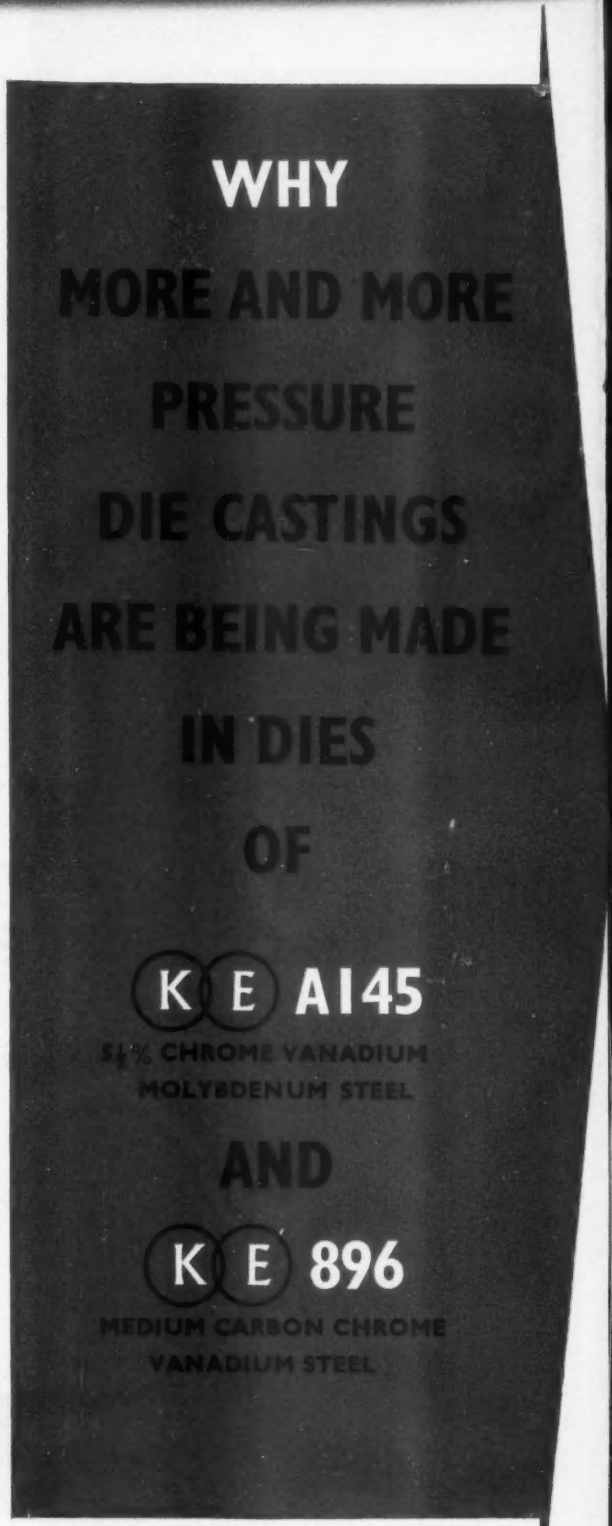
have unusual properties which suggest their use as non-aqueous anti-foam agents, base stocks for solvent-resistant grease and coatings, anti-static agents, plasticizers and additives for plastics, and as components for polishes. The dielectric constant of these fluids ranges from about 3 to 20 at 60 cps, as compared with from 2·5 to 3·0 for standard silicone fluids. Their high polarity, resulting from the presence of nitrile groups, makes them insoluble in non-polar solvents such as alipathic and aromatic hydrocarbons. They are soluble in certain polar solvents such as alcohols, ketones, and ethers. Thermal-stability tests indicate their possible usefulness for long periods at operating temperatures of 150°C.

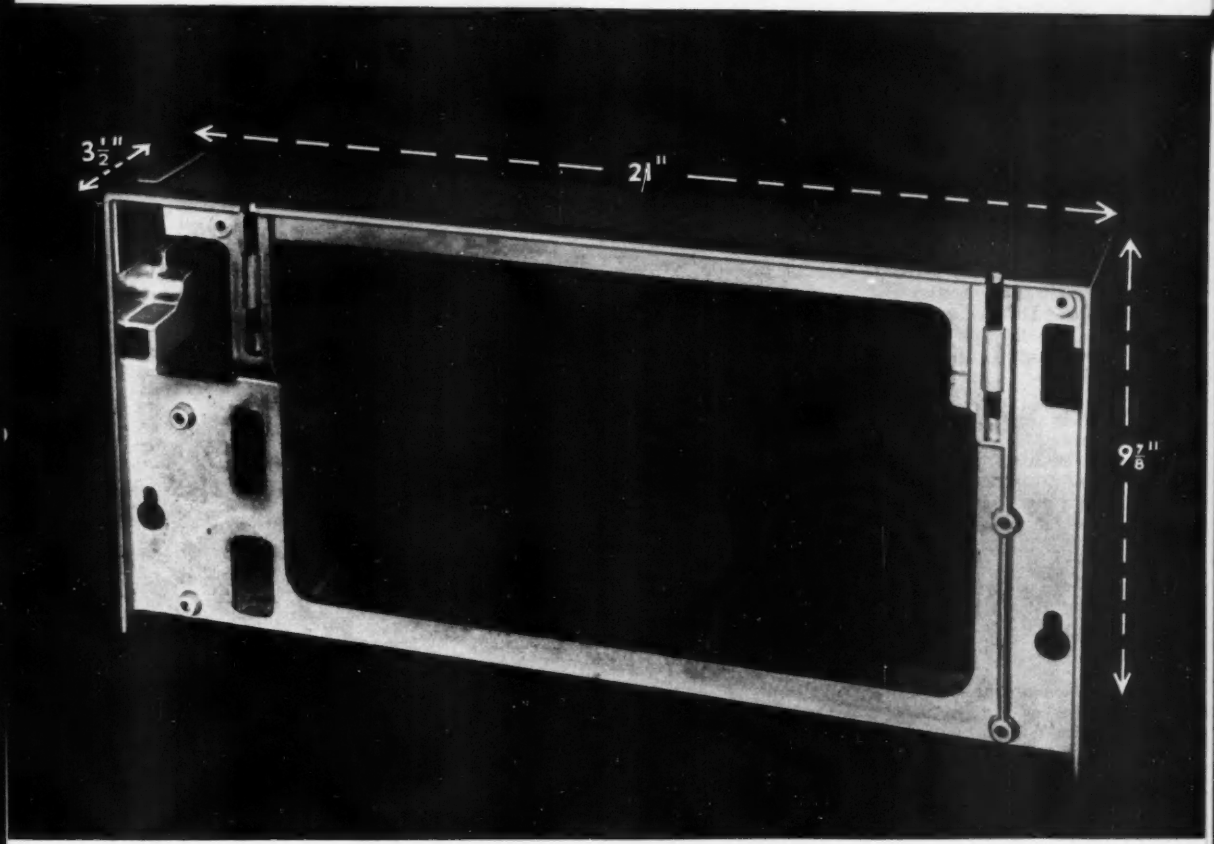
* * *

According to an article in *Svarochnoye Proizvodstvo* for July 1961, tests have been carried out in Russia in connection with **increasing the strength of welded joints between heat-resistant steels** by rolling the joints between two steel rollers, followed by artificial ageing. In these tests, the steel rollers used were of from 80 to 110 mm in diameter, the rolling force applied varying between 3200 and 14,000 kg, and artificial ageing was carried out at a temperature between 400 and 500°C. It is stated that this process resulted in a marked improvement in the mechanical properties of the joints, which otherwise, owing to their predominantly austenitic structure, have an inferior strength to that of the heat-resistant parent metals.

* * *

A new **dosimeter for measuring accumulated radiation** basically consists of a small vacuum tube containing a form of calcium fluoride. When heated, the dosimeter emits light in the blue-green region of the spectrum, its brightness being directly proportional to the radiation trapped by the calcium fluoride. In this way, a constant, cumulative record of all ionizing radiation to which a person is exposed can be kept. The device, which has a storage time up to at least two weeks and which can be re-used by renewing the fluoride, can detect and record from 1 to 300,000 roentgens, equivalent to radiation ranging from that of a luminous watch dial to that from an atomic reactor. A smaller version is designed to be implanted in the body to determine the radiation of a part such as a bone or a lung. In this case, the dosimeter can detect as little as 0·01 roentgen.





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This booklet, giving greater detail of these and other steels, is available free on request.

BUSINESS NOTES

The welding business of **The English Electric Co. Ltd.** has now been co-ordinated in a newly formed Welding Equipment Division, which has been set up at the company's Accrington Works (Tel: Accrington 33241). The manager of the Division is Mr. R. H. Boughton, the chief engineer is Mr. F. Mullery, and the sales manager is Mr. E. H. Ayres.

* * *

It is announced by **The Glacier Metal Co. Ltd.**, of Alperton, Wembley, Middlesex, that arrangements are well advanced for the formation of two subsidiary companies in New Zealand and South Africa respectively for the manufacture of plain bearings in New Zealand and South African markets. In both cases, Glacier will hold the major proportion of the equity capital and New Zealand and South African interests the remainder, the initial capital of each company being about £50,000. Production is expected to start in from nine to twelve months.

* * *

The Vibration Division of **W. Bryan Savage Ltd.**, a member of the **Pye Group of Companies**, has now become a separate company. The new company, known as **Pye-Ling Ltd.**, is a joint undertaking launched by **Pye Ltd.**, of Cambridge, and **Ling Temco Electronics Inc.**, of Dallas, Texas, U.S.A.

* * *

In order to complement their respective ranges of thermostatic and other control devices, **The Rheostatic Co. Ltd.**, of Slough, Bucks., (a subsidiary of **Elliott-Automation**) and **Robertshaw Controls S.A.**, of Geneva, Switzerland, (a subsidiary of the **Robertshaw-Fulton Controls Company**, of Richmond, Va., U.S.A.) have signed agreements covering two-way co-operation in a wide variety of devices in fields of common interest.

* * *

The Chemical Engineering Division of **W. C. Holmes & Co. Ltd.**, of Turnbridge, Huddersfield, has obtained a licence from the **International Engineering and Trading Society N.V.**, of Holland, to market the "Kathabar" humidity conditioning system in the U.K. This system, which was developed by the **Surface Combustion Corporation**, of Ohio, U.S.A., is based on the drying properties of kathene, a liquid absorbent whose main constituent is lithium chloride.

* * *

In order to extend their activities in the field of "sealed-for-life" bearings for the automotive industry, **Engineering Productions (Clevedon) Ltd.**, of Clevedon, Somerset, announce their intention to manufacture under exclusive licence from the **American Metal Products Company**, of Detroit, Michigan, the latter company's range of "Fiberglide" dry bearings, which are based on the use of woven Teflon fibre, and which are extensively used in suspension ball-joints, steering linkages, suspension-arm pivot bushings, and spring pivot bushings. The British company has already introduced their own range of "sealed-for-life" bearing designs in the U.K.,

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BUSINESS NOTES

and these designs are currently in production for a number of well-known cars. This new association makes it possible for them to offer motor manufacturers a comprehensive range of dry bearings.

* * *

Extending their Telex facilities already available at Hull, Birmingham, Manchester, and London, **J. H. Fenner & Co. Ltd.** announce that the Telex number of their Glasgow branch is 77269.

* * *

The Manchester office of **The David Brown Corporation (Sales) Ltd.** is now located at Ashburton Road, Trafford Park, Manchester 17 (Tel: Trafford Park 4751/2). This move coincides with the transfer of the company's Machine-Tool Division to these premises from Britannia Works, Sherborne Street, Manchester.

* * *

"Furnascote" refractory coatings, formerly manufactured and marketed by **Corrosion Ltd.**, of Southampton, will in future be manufactured and marketed by **Furnascote Ltd.**, who will operate from 16/18 Malvern Road, Southampton (Tel: Southampton 71347). All enquiries and correspondence should be sent to the sales director, Mr. G. L. Barron, A.I.R.I.(Sc.).

* * *

The complete London sales organization of the **John Thompson Group of Engineering Companies** is now centralized in a new headquarters building in Woburn Walk, Duke's Road, off Tavistock Square, London, W.C.1. Some companies in the Group were previously located at Imperial House, Kingsway, and others were in various parts of London; now, however, seventeen companies are represented in the new building, which forms a new east wing to the extensive Tavistock House of the British Medical Association. Wolverhampton remains the head office of the Group and for the majority of individual firms, but among the companies which have recently entered the John Thompson Group and which are now represented in the new London office are **Thompson Brothers, Darham Industries, John Thompson Compost Plant Ltd.**, and **Thompson-Tappan.**

* * *

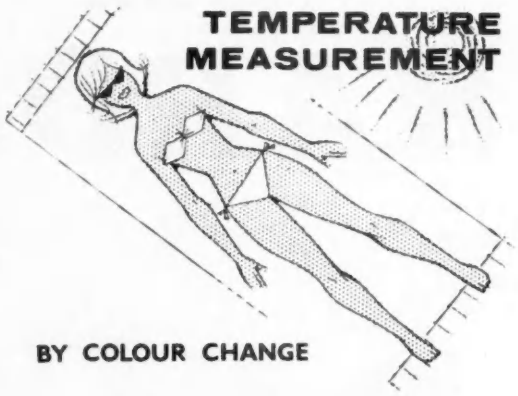
The **Philco Corporation,** of Philadelphia, Penn., have sold their minority interest in **Semiconductors Ltd.**, of Swindon, Wilts., to **The Plessey Co. Ltd.** As a result of this transaction, Semiconductors Ltd. become the wholly owned subsidiary of Plessey and continue as a non-exclusive licensee of Philco with respect to the manufacture and sale of transistors.

* * *

F. Pratt & Co. Ltd., of Halifax, Yorks., manufacturers of chucks and workholding devices, have been reconstituted as a holding company under the name of the **F. Pratt Engineering Corporation Ltd.** A new wholly owned subsidiary has been formed, under the name of **F. Pratt & Co. Ltd.**, to carry on the existing manufacture and marketing of the company's products. The parent company's two other wholly owned subsidiaries are **E. Burnerd & Co. Ltd., Pratt Precision Hydraulics, Ltd.,** and the **Winchester Tool Corporation, Inc.,** of America. The re-organization of the parent company as a purely holding company has been brought about by the present volume of business and in anticipation of future developments, including the possible formation of a fifth wholly owned subsidiary, to trade in the European Common Market.

* * *

Representing another step in the development of the production technique of electrochemical machining, a new company, **Metachemical Machines Ltd.**, has been formed on an equal partnership basis by **B.S.A. Tools Ltd.**, of Birmingham, and **Metachemical Processes Ltd.**, of Crawley. The technique originated in research sponsored by the **Steel Improvement & Forge Co. (SIFCO),** of Cleveland, Ohio. Metachemical Processes Ltd. are the British associates of SIFCO and, as a result of a variety of new agreements, the technical information from SIFCO and their other associates is now available to Metachemical Machines Ltd. While the scientific work of the new company will be carried out at its Crawley headquarters, production will be undertaken initially by the **Kenworthy Jig & Press Tool Co. Ltd.**, of Morden, which Metachemical Machines Ltd. have acquired as a wholly owned subsidiary. On the home market, the new company's products will be marketed by **Burton, Griffiths & Co. Ltd.**, of Kitt's Green, Birmingham, the U.K. selling organization of the **B.S.A. Tools Group.** Sales in overseas markets will be organized through the existing export network of B.S.A. Tools Ltd.



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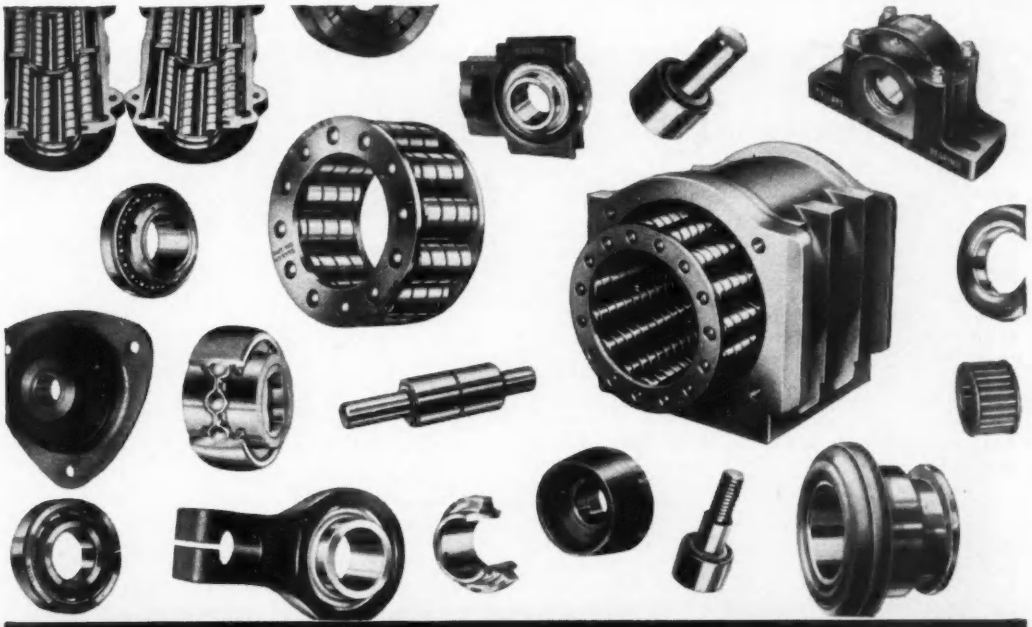

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Mirrlees, Bickerton & Day Ltd. have received an order, valued at £500,000, from Centromor Ltd., of Warsaw, the Polish Government's Central Import and Export Office for Marine Equipment, for 13 Mirrlees 6-cylinder diesel engines, each developing 1600 bhp at 400 rpm. These engines will be installed in distant-water stern trawlers now being built at the Gydnia shipyard in Poland. Delivery of the first engine is scheduled for October 1962. Each unit, turbocharged and with air-charge cooling, drives through a flexible coupling and a 2 : 1 reduction gearbox to a controllable-pitch propeller. The specially designed gearbox also drives a ship's-service generator to supply the power necessary for all heating and lighting aboard and for a 240-kW trawl-winch generator.

* * *

Believed to be the largest of its type in Europe, a steam-raising plant, providing a high steam output for industrial space heating and processed by a multiple installation of large shell-type boilers, is to be built for the Industrial Estates Management Corporation for Wales. Steam will be supplied from a centralized source to some 34 factories on the Treforest Industrial Estate, near Pontypridd, South Wales, the boiler plant comprising eight oil-fired super-economic shell-type boilers with superheaters, to meet a maximum station demand of about 200,000 lb/hr of steam at 250 psi and 600°F. Each of the eight boilers has a capacity of more than 30,000 lb/hr, with standby for all load conditions. The contract for the complete plant has been placed with John Thompson (Wolverhampton) Ltd., who, in addition to designing and manufacturing the boilers, will be able to utilize the resources of their associate companies in the Group.

* * *

It is announced by British Insulated Callender's Cables Ltd. that they have been awarded a £1,000,000 contract from the Indian Railway Board for the supply and installation of overhead equipment for 25-kV, 50-cps, a.c. railway electrification over 250 track miles of suburban railway in the Calcutta area. With this latest contract, the third of its type received by the company from the same source since December 1958, the Group will have been responsible for nearly 1000 track miles of similar electrification at a cost of some £4,700,000.

* * *

Completing an order worth about £75,000 for six broaching machines, complete with tooling, all to Lapointe standard design, a 15-ton, 90-in. stroke double-ram vertical broaching machine has been shipped from the Watford factory of the Lapointe Machine Tool Co. Ltd., for installation in the plant of General Motors at Buenos Aires, Argentina. The machine, which has a cutting speed of 40 fpm, has broaches fitted with carbide-tipped teeth to General Motor's specifications for producing the contour of cluster bearings weighing 16 lb for Bedford trucks at a rate of 32 per hour. This is the first machine to be built in the U.K. for export to South America, using carbide-tipped broaches for a contour broaching operation.

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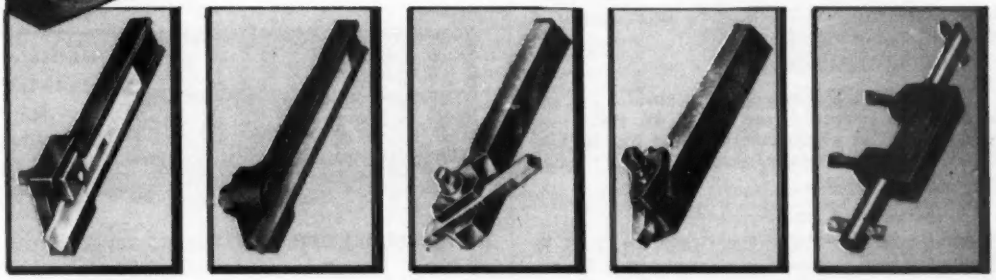

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UT19

PERSONAL

Walker Crosweller & Co. Ltd. announce that **Mr. G. L. J. Weaver** has been appointed general manager of their Instrument Division.

* * *

Mr. S. J. Parsons, B.Sc., A.M.I.E.E., has been appointed general manager of the Electrical Division of The Expanded Metal Co. Ltd., in succession to **Col. H. F. Langley,** who will become, at the end of September 1961, chairman of The Cressall Manufacturing Company, a subsidiary of The Expanded Metal Co. Ltd. Mr. Parsons also joins the Cressall board of directors, while Colonel Langley remains on the board of the parent organization.

* * *

It is announced that **Mr. F. Bradford,** general manager of the Production Division, and **Mr. F. Smith, M.Inst. M.S.M., A.M.I.Mech.E.,** general sales manager, have been co-opted to the board of directors of Headland Engineering Developments Ltd., a member of the Headland Group of companies.

* * *

Allis-Chalmers Great Britain Ltd. announce the appointment of **Mr. T. H. Kindersley, M.A., A.M.I.C.E.,** as chief engineer of the company's Engineering Products Division at their London office at Salisbury House, London Wall.

* * *

Plessey Nucleonics Ltd., one of the Plessey Group of Companies, announce the appointment of **Captain G. R. B. Pattison, C.B.E., B.Sc., M.I.E.E., R.N. (Retired),** as deputy general manager.

* * *

Mr. C. F. Hurst has been appointed assistant managing director of Samuel Osborn & Co. Ltd. Mr. Hurst is now deputy chairman and assistant managing director of the company.

* * *

Owing to pressure of other business commitments, **Sir Peter Roberts, Bart., M.A., M.P.,** has resigned from the board of Staveley Industries Ltd.

* * *

Mr. W. Morris, secretary of Colt Ventilation Ltd. and its associated companies, and **Mr. F. W. Price,** sales manager of Colt Ventilation Ltd. and W. H. Colt (London) Ltd., have been appointed directors of the Colt Associated Companies.

* * *

As announced by the Perkins Group, **Mr. T. H. R. Perkins** has been appointed assistant managing director and continues as marketing director of the Group. **Mr. D. F. W. McNair,** formerly the Group project co-ordinator, has been appointed deputy director of marketing of the Group, while **Mr. H. Lymath** succeeds

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PERSONAL

Mr. McNair as Group project co-ordinator. **Mr. J. M. Collins,** a director of Perkins Engines Ltd., has been appointed general manager of the Group's sales division. In addition to his present directorships of Perkins overseas companies, Mr. Collins has been appointed a director of Perkins Outboard Motors Ltd. and of Perkins Gas Turbines Ltd.

* * *

Mr. E. W. B. Owen, Mr. E. M. de Windt, and **Mr. R. K. Nelson** have joined the board of directors of Eaton Axles Ltd., of Great Sankey, Warrington. Mr. Owen is joint managing director of Rubery, Owen & Co. Ltd., while Mr. de. Windt is vice-president of the Eaton Manufacturing Co. and Mr. Nelson was formerly assistant chief engineer of the Eaton Manufacturing Co.

* * *

It is announced by The English Electric Co. Ltd. that **Mr. B. Feltbower, B.Sc.(Eng.), M.I.E.E.,** has been appointed chief engineer of the company's Control-Gear Division at Kidsgrove, Stoke-on-Trent. Mr. Feltbower will be responsible for all the technical administration and new projects of the Division, which specializes in all aspects of electric-motor control and the engineering of automatic control schemes for industrial processes.

* * *

Owing to ill-health, **Mr. B. L. Goodlet, O.B.E., Sc.D., M.I.Mech.E., M.I.E.E.,** is retiring from his position of managing director of the Brush Electrical Engineering Co. Ltd., of Loughborough. Dr. Goodlet will, however, continue in a less arduous post as vice-chairman. **Mr. J. E. Smith, M.I.Mar.E.,** at present managing director of The National Gas & Oil Engine Co. Ltd., will assume the position of managing director of the Brush Electrical Engineering Co. Ltd.

* * *

Cochran & Co., Annan Ltd., announce that **Mr. H. M. Simpson** has been appointed chief engineer of the company.

* * *

Following the recent merger between The Delta Metal Co. Ltd. and Enfield Rolled Metals Ltd., the chairman of the board of Delta-Enfield Rolled Metals Ltd., is the **Rt. Hon. The Earl of Verulam** and the vice-chairman is **Mr. C. C. Millar, B.Com., F.C.A.** The managing director is **Mr. A. Lane.** The remainder of the board comprises **Mr. W. W. Dolton, Mr. S. Powell,** and **Mr. W. J. Vaughton.** The company secretary is **Mr. W. W. Rigg, A.C.A.**

* * *

As announced by R. B. Pullin & Co. Ltd., **Mr. S. Jones, Ph.D.,** has joined the company as technical director. Until recently, Dr. Jones was director of research applications at the Central Electricity Board, where he was responsible for the development of a number of research projects, and more particularly of automatic process controls systems.

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AP88

NEWS ROUND-UP

Electrical Manufacturers' Views on Future Screw-Thread Practice

The British Electrical and Allied Manufacturers' Association (BEAMA) has had the problem of future screw-thread practice under consideration for some years and, following the decision of the International Standards Organization to issue recommendations for both unified inch and metric systems, a detailed enquiry has been made among individual member firms.

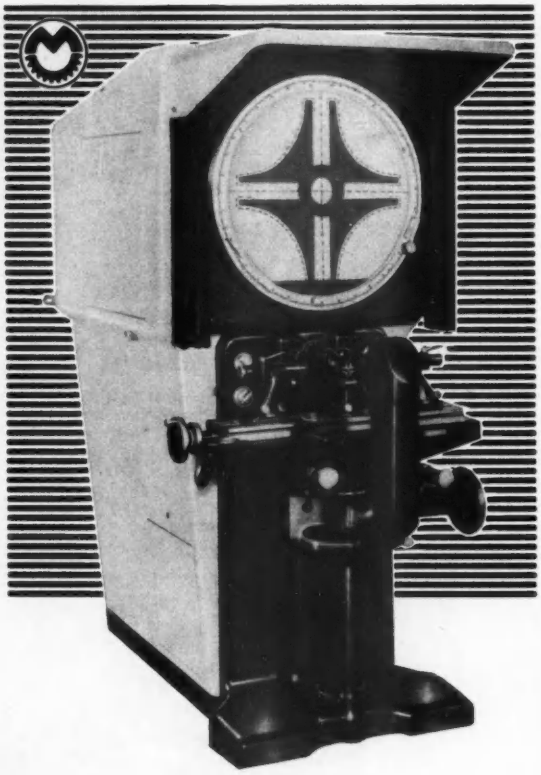
The BEAMA Council has now issued a statement summarizing the results of this enquiry. In this statement, the BEAMA Council points out that the enquiry was directed towards long-term consideration of all the many relevant factors which should influence the industry's future screw-thread policy. These considerations included the importance to the electrical industry and its customers of having a common screw-thread policy, the significance to the industry's export trade (not only in the Commonwealth and Europe, but also throughout the world), and generally an attempt to foresee long-term trends.

The enquiry has revealed that a substantial majority opinion amongst BEAMA members is that it is desirable to maintain a common normal production practice within the electrical and allied industries and that, when the time comes to make a change, it should be to the I.S.O. metric thread. In the light of this consensus of opinions of its members, BEAMA intends to initiate discussions with the major customer, trade, and Government interests with which they are concerned, so as to seek to work out an acceptable long-term plan for giving effect to this future screw-thread policy.

Why Many British Firms Fail to Export

For the first time, a survey has been carried out into company attitudes to exporting and pinpoints the real reasons why many British firms fail to export. The survey was carried out by Marplan Ltd., of London, E.C.4, on behalf of the Institute of Directors' Export Action Now Committee, and copies have been sent to the Chancellor of the Exchequer and to the President of the Board of Trade. A total of 52 firms was questioned —all with less than 300 employees—the survey being confined to the smaller firms because it was felt that it was among these that the greatest expansion of exports was possible.

Quoting from the report, it is stated that "perhaps the most pronounced feature of this enquiry was the difference in the amount of interest exhibited in exporting and the conspicuously low proportion of managing directors who were really enthusiastic about, or even interested in, this side of their business. Many of these manufacturers tend to lack confidence in their ability to capture and sell in overseas markets. In a number of respects, they feel their firms are too small to adapt their goods for foreign markets, or to employ an export manager—or even a clerk—to deal efficiently with their export trade, or to allow the managing director to travel abroad and make the necessary contacts. However, this lack of confidence has spread further. A fair number of the manufacturers interviewed are diffident about the



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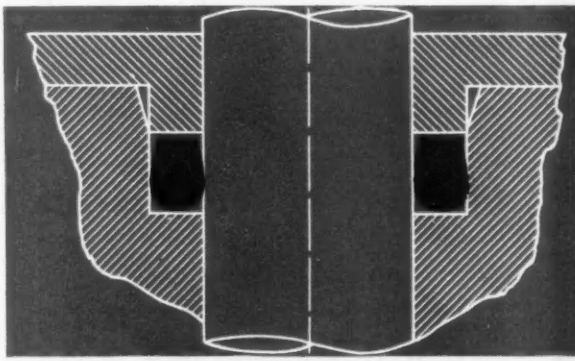

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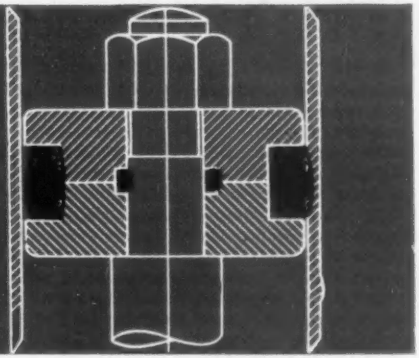

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success of the export drive, and look on competitors such as Germany not with any idea of emulation, but with resignation at their seizure of former British markets. Their attitude to new overseas markets is not adventurous, and many enquiries which come to the firm are ignored or summarily dismissed as impossible".

Of the firms surveyed, about 25% were exporting vigorously, the exports of 50% were declining or stationary at a low level, and just under 25% had never exported and were not really interested in doing so. Less than 10% of the non-exporting firms wanted to export, but did not know how to set about it.

A remarkable fact brought to light was the difference of opinion between the managing directors of exporting companies and non-exporting companies. Those who exported found that they could easily get export information, that the Board of Trade was helpful, and that lack of foreign languages was no barrier to trade. Many non-exporters, however, gave these reasons as the prime cause for not entering the markets abroad. The report concludes that these differences are often excuses rather than valid reasons, and states that in most cases the manufacturer's failure to export successfully "is a function not of any external circumstances, but of his general attitude towards exports; it is not that he *cannot* export, but simply that he does not want to".

Most manufacturers agreed that a high level of home-market demand deterred them from exploring export possibilities. In this connection, the report says that "equally striking, and possibly rather frightening, is the almost complete failure to realize that any really major reduction in home demand would almost certainly be the consequence of a world trade recession which might well close up the possibility of exports".

The non-exporters fell into five categories, i.e., (1) the unambitious, (2) the cautious, (3) the "too-small" firms, (4) the "too-busy" director, and (5) the "too-old" or "too-ill" director. "While it is unlikely that the future of the British export trade will lie with these firms" the report comments, "it is still clear that a large number of firms which are working in the home market at a reasonable level of efficiency could well improve their own position by proper attention to exports".

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Automatic and Fluid Transmissions. By J. G. Giles, B.Sc.(Eng.), M.I.Mech.E., A.M.I.E.E. 328 pp., 217 illustrations. Publishers: Odhams Press Ltd., 96 Long Acre, London, W.C.2. Price: 45/–.

The author of this well-written and produced book is an accomplished automobile research engineer who has for many years specialized in the study of transmission problems and who has published several papers and reports on this subject. In this book, the first British study to cover both the principles and practical aspects of the design, installation, and operation of automatic and fluid transmissions, he puts on record details of the history of automatic transmission devices and describes the operating performance of all the more important mechanisms at present available.

Mechanical, electric, and hydraulic systems are dealt with, together with semi-automatic devices and overdrives. Most of the proprietary American, British, and Continental transmissions are reviewed in some detail, and mention is made of some devices still under development. While the main emphasis is on automobile applications, the field of heavy transport is not neglected, and information is given on transmissions designed for buses, heavy goods vehicles, railcars, locomotives, tractors, etc. This authoritative work will prove of exceptional interest and much practical value to engineers on both the manufacturing and servicing sides of the motor industry, to students of automobile engineering, and to others interested in the design of motor vehicles.

Aids to Machine-Shop Practice. By C. T. Bower, A.M.I.Prod.E. 208 pp., 203 illustrations. Publishers: Odhams Press Ltd., 96 Long Acre, London, W.C.2. Price: 18/–.

Containing over 200 practical hints, new methods and ideas, designs for new devices, improved production methods, and suggestions for saving time, simplifying work, and increasing output, this interesting book is a comprehensive storehouse of novel and ingenious ideas designed to aid production engineers, maintenance engineers, draughtsmen, machine operators, toolmakers, and others concerned with engineering production. No attempt has been made to copy equipment already available commercially and, in general, the ideas suggested are both simple and inexpensive.

The various items in this volume have been grouped into sections to assist rapid reference and cover such subjects as assembly methods, drawing-office aids, drilling and tapping, gauging, grinding, milling, handling methods, lathe work, maintenance, marking-out, production methods, welding, and jigs, fixtures, and attachments. Drawings and photographs are included to show every essential detail, so that readers can easily make up any of the devices described or can modify machines and tools as suggested.

Semiconducting III-V Compounds. By C. Hilsum and A. C. Rose-Innes. 250 pp., 137 illustrations. Publishers: Pergamon Press Ltd., Headington Hill Hall, Oxford. Price: 60/–.

During the past ten years, increasing interest has been aroused in the semiconducting properties of compounds of elements from Groups III and V of the Periodic Table. This interesting and well-produced book therefore fills a definite demand in that it describes the properties of III–V compounds as a family of semiconducting crystals, and also relates these compounds to the better-known and understood monatomic semiconductors, i.e., silicon and germanium, together with details of their applications. As such, it is a valuable reference work for physicists, chemists, and engineers engaged in research and development in the general field of semiconductors.

Providing a concise, but none the less comprehensive, treatment of the theoretical and experimental aspects of the subject, the book deals with band structure, crystal structure, preparatory techniques, transport processes, optical absorption, photo-electric effects, and galvanomagnetic properties, as well as with a number of device applications. In addition, detailed discussions are given of certain physical processes which are of minor importance or entirely absent in element semiconductors. but which are very prominent in III–V compounds. The text is supplemented by a wealth of excellent and pertinent illustrations, and an unusually comprehensive index is included.

Cold Forging of Steel. By Dr.-Ing. Heinz D. Feldmann. 268 pp., 156 illustrations. Publishers: Hutchinson & Co. (Publishers) Ltd., 178-202 Great Portland Street, London, W.1. Price: 40/–.

First published in Western Germany in 1959, under the title of "Fliesspressen von Stahl", this first English edition, translated by A. M. Hayward, serves to bring to a much wider audience a general statement of the process of the cold-forging of steel, in the light of the experience and knowledge now gained. In this connection, it should be noted that, although cold-forging is a process that has been known and used for about sixty years, its application to the manufacture of steel products dates back no more than twenty-five years and, until 1945, was kept secret as a process mainly applied to the manufacture of war munitions.

Beautifully produced and illustrated, this outstanding book provides for the first time a comprehensive description of the process. What is more to the point, its author—probably the foremost expert on the subject in the world—writes clearly and interestingly, as well as authoritatively. The basic theory, supported by formulae and examples of the theories applied in practice, is discussed; in addition, for the benefit of practical engineers and manufacturers, the practice of cold-forging is introduced, and details are given as to how it fits into present industry. As such, this book will undoubtedly help to accelerate further progress in this field.

Engineer Apprentice Manual. 400 pp., 482 illustrations. Publishers: The Trade & Technical Press Ltd., 55a Stonecot Hill, Sutton, Surrey. Price: 42/–.

Many otherwise excellent textbooks tend to be either too theoretical or academically practical, with the result that they are of limited value in providing hints and help on the shop floor. This book, which has been compiled from selected articles originally published in "Engineer Apprentice", obviates the deficiencies of such textbooks by providing a record of useful information and hints of practical value to engineering apprentices and students. As such, it serves as a reference work not only during the whole period of apprenticeship, but also later on when a young engineer is left to his own devices. In many ways, too, it is a useful refresher course for experienced engineers.

The contents are simply and lucidly written, and are enlivened by a wealth of judiciously selected illustrative matter in the form of line drawings and photographs. The subjects covered are, of necessity, comprehensive, and include work in the drawing office and the foundry, as well as machine and other tools, mechanical and electrical equipment, hydraulic and pneumatic equipment, metal polishing and degreasing, workshop hints, and useful formulae. In short, this is undoubtedly one of the best books of its kind ever published.

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12. Automatic Jig Boring and Milling Machines

Designed for fully-automatic control through the use of punched cards or tapes, a range of automatic setting, jig-boring, and milling machines is presented in a 28-page brochure. A wide range of auxiliary equipment is supplied enabling to carry out such diverse operations as copy-milling, staircase milling from a master form, jig boring to an extremely high accuracy, etc.

13. Flash Evaporators

Suitable for marine and land applications, a range of two-stage flash evaporators is dealt with in an 8-page brochure. The unit is complete with brine and distilled-water pumps and distiller, external feed heater and steam-jet air ejector, and provides in 24 hours 20 to 75 tons of water.

14. Industrial Diesel Engines

Three illustrated 8-page brochures describe a range of normally-aspirated pressure-charged and pressure-charged intercooled industrial diesel engines with horse-power ranges of from 138 to 2440 bhp. Details of design and construction are given, and comprehensive data on speeds, fuel consumption, and compression ratios are also incorporated.

15. Limit Switches

Providing high contact pressure, low impact, and simplicity of design and maintenance, a range of machine-tool limit switches is presented in a 4-page folder. The switches are water, oil, and dust tight and are suitable for a wide variety of contact arrangements.

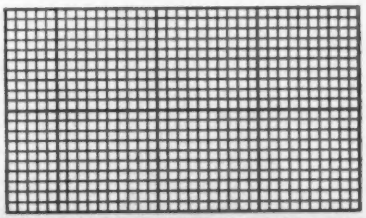
16. High-Tensile V-Belts

Incorporating an endless nylon core which is treated with a bonding solution and coated with synthetic rubber to resist oil and heat, a range of high-tensile V-belt drives is introduced in a 12-page catalogue. Elastic endless belts, hexagon belts, and heald straps are also dealt with.

How do they roll top hats?

As section minded people are aware, "top hat" is just a name for one of our many thousands of standard sections. Our motto has always been "tell us the shape and we will make it", so whatever shape a designer requires we can cold roll it accurately in any quantity or length.

Sketch your section for us— we will quote without obligation.



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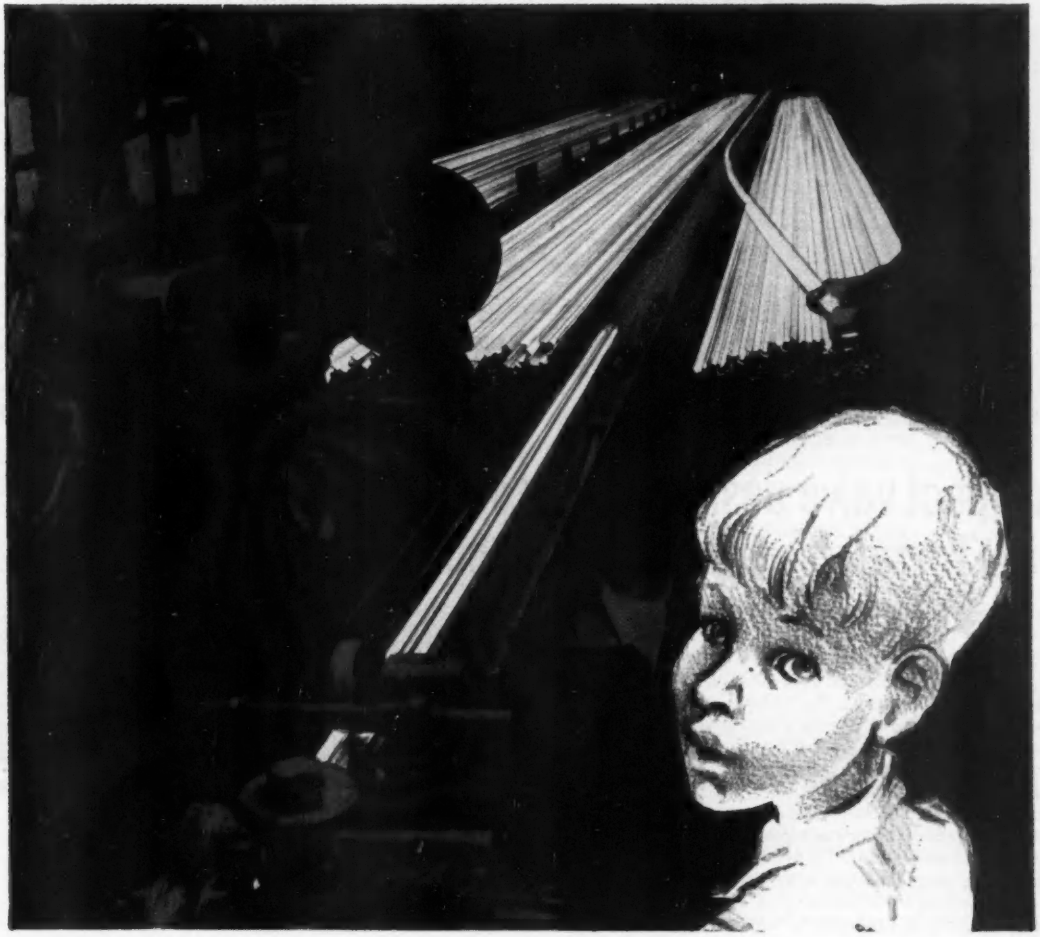

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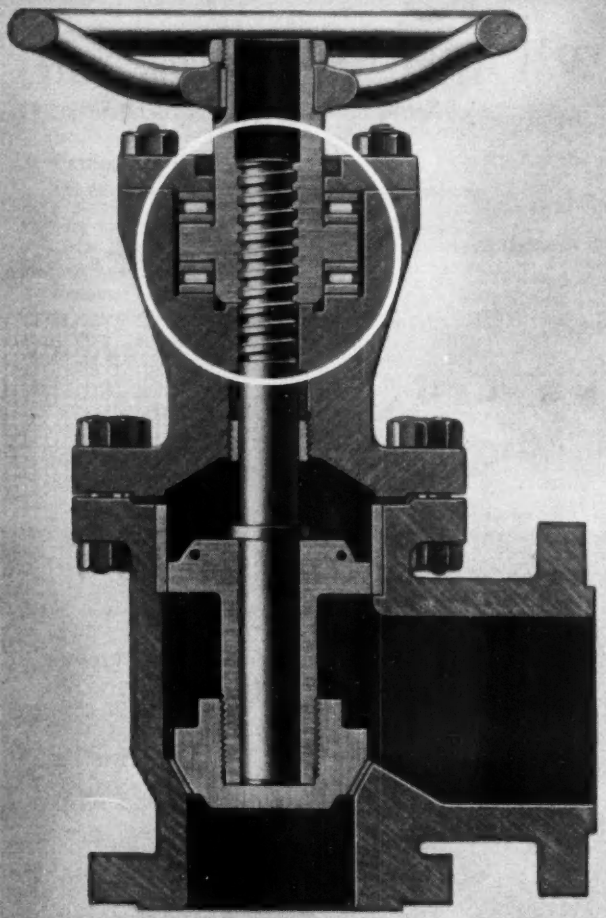

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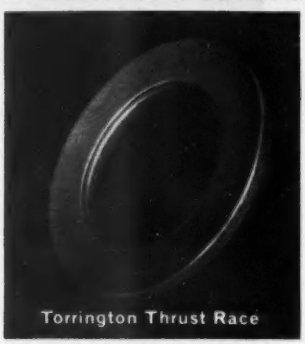

Compact valve design, easier operation with Torrington needle thrust bearings

High thrust capacity, thin cross section and low unit cost have made Torrington Needle Thrust Bearings a natural choice for top valve performance. With Torrington Needle Thrust Bearings, only a fraction of the normal closing effort is needed. This puts less strain on the valve . . . means smoother, more reliable operation. Lifetime pregreasing ensures peak efficiency over years of extra service life. Torrington Needle Thrust Bearings are exceptionally compact. They provide an assembled height of far less than any other type of thrust bearing. They may be run directly on adjacent hardened and ground surfaces or, as shown above, on standard Torrington thrust races. If you make gate valves, globe valves, angle valves—in fact any valve closed on a threaded stem—you'll find it pays to investigate the top efficiency of Torrington Needle Thrust Bearings. Our Technical Representative will be pleased to call on you.

TORRINGTON BEARINGS

THE TORRINGTON COMPANY LTD

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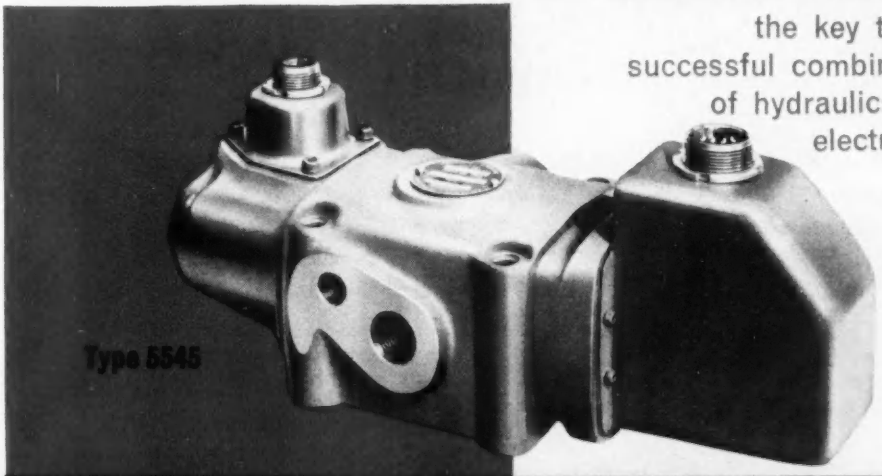
Hydraulics

ELECTRO HYDRAULIC SERVO VALVES

the key to the successful combination of hydraulics and electronics



The Keelavite electro-hydraulic servo valve consists of a rotary torque motor driving a pilot valve, which provides one stage of hydraulic amplification, to control the position of the second stage piston.

Two sizes of valve are currently available:

Type 5545 giving a flow for a pressure drop of 1000 psi of 25-30 gpm., and

Type 5572 giving a flow for a pressure drop of 1000 psi of 100 gpm.

The first stage consists of a nominally zero lapped 3-way valve, which is driven against springs by a rotary torque motor. Balanced windings are fitted to the torque motor. These may be either low or high impedance. An inductive rotary pick-up, also driven by the torque motor, is used to close a feed-back loop around the pilot valve.

The second stage consists of a conventional piston type valve, which may be fitted with either a 4-way or 5-way piston. The body is made of close grain cast iron. Zero, under and overlapped pistons are available. Internal leakage and flow linearity with deflection are both dependent on piston lap.

THE RECOGNISED AUTHORITY ON HYDRAULIC POWER TRANSMISSION

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- Aluminium and magnesium alloy castings by sand, die, shell and plaster mould methods.
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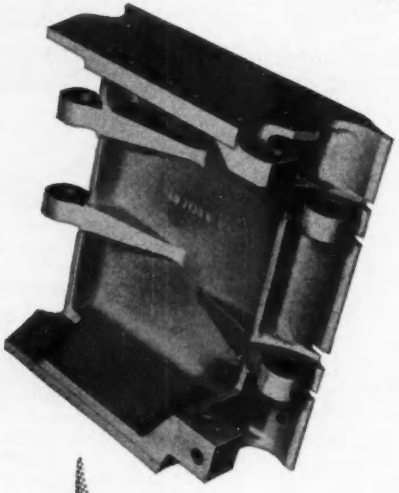

Magnesium Alloy Carriage Casting for Canning 'Uniflex' Buffing Machine. Weight 23 lb. By courtesy of W. Canning & Co Limited.

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A WELDER'S BEST FRIEND IS A FORD ENGINE

Electric welding sets in a wide range of types and sizes are now available with Ford power-units installed. These are the ones to choose! Every Ford Industrial engine—Diesel or Petrol—is built to modern designs in one of the best-equipped factories in Europe. Ford Industrial engines are tough, economical and outstandingly reliable. And they are backed by the famous Ford service—with factory-trained service engineers and stocks of genuine Ford parts close at hand anywhere in the world. For long life, least trouble and lowest running and maintenance costs, choose welding equipment fitted with a Ford Diesel or Petrol power unit. Send the coupon below for details of Ford-powered equipment of the type you are interested in.

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Please send me details of Ford-powered equipment of the following types.

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HEAT EXCHANGERS

BROWN INTEGRAL 'ONE-PIECE' FINTUBES HAVE MANY TIMES THE HEAT TRANSFER CAPACITY OF BARE PIPE.

Increased production facilities to meet the ever increasing demand for the finest heat exchange unit—BROWN FINTUBES. As specialists in heat exchange problems and actual makers of Brown Fintubes, we can now offer even better terms and even finer service. If you have a heat exchange problem we can offer: LOWER FIRST COSTS by improved and bigger production—LOWER PLANNING AND INSTALLATION COSTS by greater standardisation—LOWER MAINTENANCE COSTS by maximum interchangeability of standard components.

They provide great flexibility in the number, height and length of the fins joined to the centre tube, and give designers and engineers maximum opportunity to balance the primary and secondary surfaces to the needs of the fluids being handled, saving pipe, weight space, installation and maintenance.

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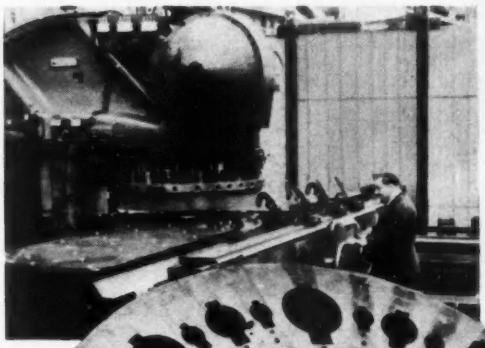
Meehanite

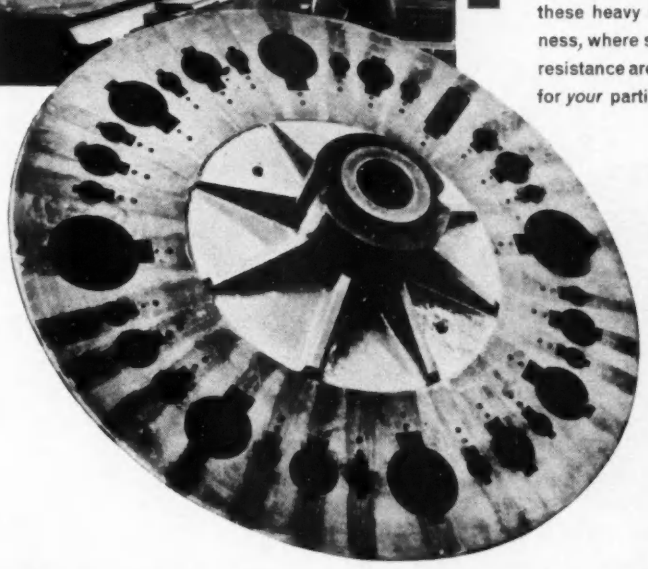
Casting Control for Soundness and Strength

Casting soundness is essential for casting strength. Meehanite casting control is aimed at ensuring maximum soundness and solidity in all sections.

A typical example is the Turret casting for the Wiedemann Press. The severe stresses in service demand an exceptional degree of soundness and density in these castings. Accuracy and good wear resistance are particularly needed in the operation of punching ¼" steel sheet to close tolerances by this new process.

Meehanite has proved admirably suited for these heavy castings of 9" section thickness, where soundness, strength and wear resistance are essential. Specify Meehanite for *your* particular requirements.





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Copy of the Meehanite Specification Booklet will gladly be sent upon request. Also available for your information are leaflets on:-

A10 Casting Properties

A11 Designing Meehanite castings to cut production costs.

A12 Machine Tools

Press illustrated is produced by Distington Engineering Co., Ltd., for Dowding & Doll, Ltd., (Sole Agents). Castings by Cameron & Roberton, Ltd.

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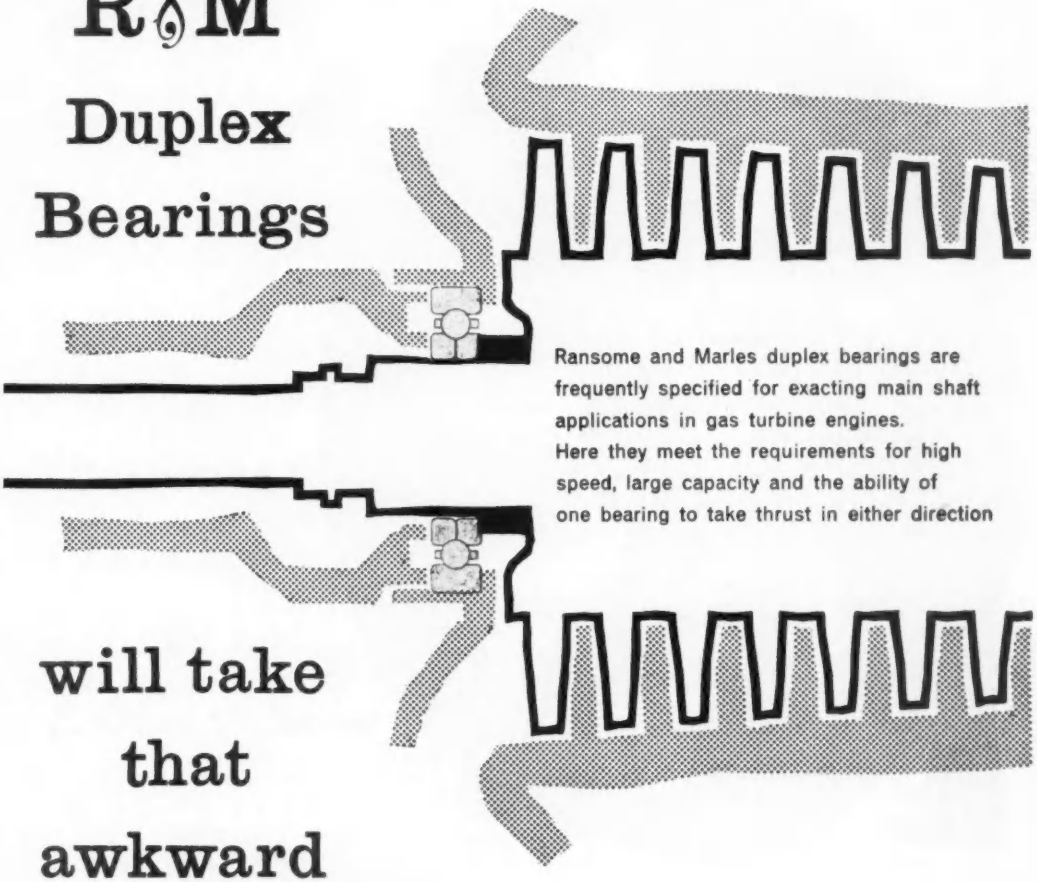
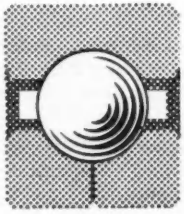
R&M Duplex Bearings



Ransome and Marles duplex bearings are frequently specified for exacting main shaft applications in gas turbine engines. Here they meet the requirements for high speed, large capacity and the ability of one bearing to take thrust in either direction

will take that awkward thrust load



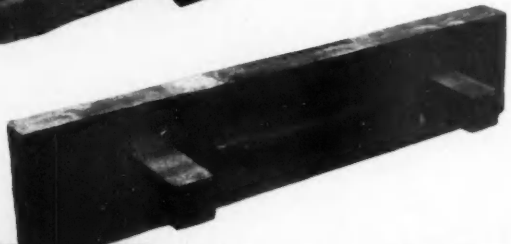
There are many other less critical applications where the duplex bearing is providing a compact solution to thrust problems. The Ransome and Marles two-piece inner design is backed by a wealth of practical experience. Publication 37 will provide you with full details of duplex and other bearings in the R&M range.

RANSOME & MARLES BEARING COMPANY LIMITED

NEWARK-ON-TRENT · NOTTS · TELEPHONE 456 · TELEX 37-626

Chrome Manganese spider casting for rod mill weight 4 tons 2 qrs.

Longer service life for all wearing parts ...



Manganese steel hammer tip weight 1 cwt. 1 qr. 25 lb.

EDGAR ALLEN'S STEEL CASTINGS

We have extremely wide experience in making steel castings for the wearing parts of jaw, roll and gyrating crushers, hammer and ball mills, liners and all crushing and grinding machinery.

We have developed special steels and alloys, and know which of these to recommend for specific duties to give the longest possible service life.

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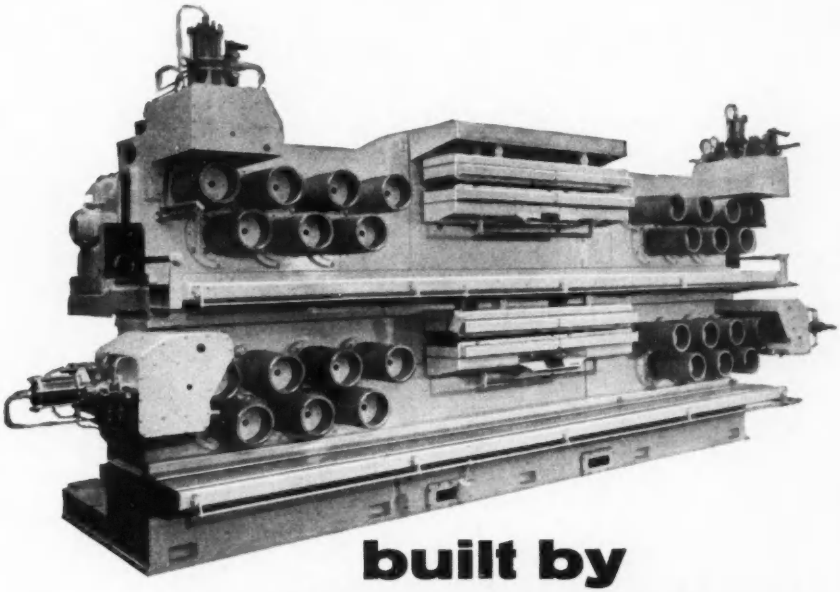

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Each Tier works independently and has seven input and seven output rolls, of increasing diameters, with a centrally situated Heater. Pneumatically powered Squeeze Rolls are fitted on the first input and the last output rolls to prevent yard slip. The input end is driven by a 5 h.p. and the output by a 9 h.p. motor, both with Heenan-Dynamatic slip couplings and brake units.

Roll Speeds: Input 94/40 rpm. Output 130/40 rpm.

Bedplate Dimensions: 14′ 6″ x 4′ 6″. Height 8′ 3″.

Weight: 17 Tons.

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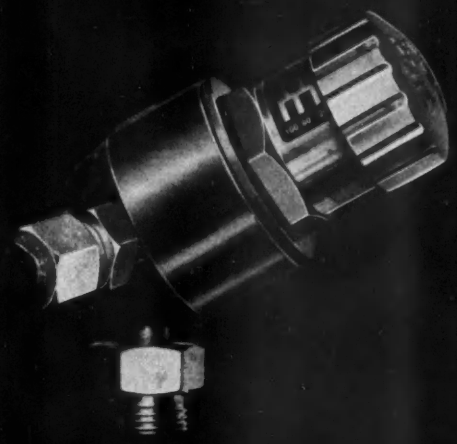
COMPRESSOR AND POWER PLANT SPECIALISTS FOR NEARLY A CENTURY

P6197



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The Sprite is a precision-built single stage regulator, made to the exacting standards of all Saturn equipment, and able to stand up to really rough handling. Maximum working pressures:

OXYGEN	100 lbs. p.s.i.
ACETYLENE	15 lbs. p.s.i.
PROPANE	20 lbs. p.s.i.

The Saturn Sprite is piston-operated for trouble-free service and safety: quick and easy to operate.

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NEWS

3 New Tool Designs

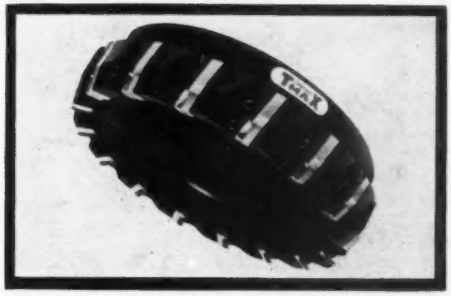
Increased production resources, now give us the opportunity of presenting:

"Throw-away" Cutters

A cutter design with throw-away economy, and the vesatility of a cutter with brazed blades.

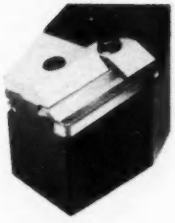
Special features:

- **Sturdy design, with easily replaceable parts.**
- **Superior economy. The cutter can be supplied with inserts of different sizes, negative as well as positive.**
- **Gives a high surface finish. The design has been specially conceived around this feature.**



Micro-blade

This revolutionary and bold idea, with a so-called "micro-blade" is now about to leave the development stage.



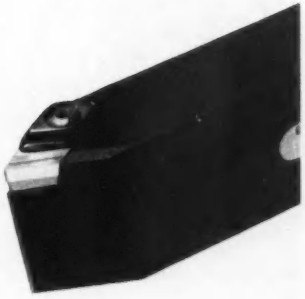
This tool which in the first place is intended for cutting depths of over 1", opens up new possibilities to improve machining economy within a range so far untouched.

Toolholder with Rhomboid inserts for Copy Turning

The copy turning tool range which includes brazed tools, toolholders with long inserts, and throw-away tools of the T-maX type with triangular standard inserts, is now extended by including this new holder.

Special features:

- **A 55° nose angle gives good accessability with most copying operations.**
- **Robust design with sound clamping of the throw-away blade.**
- **Positive cutting rake with 0° front-to-back rake allows machining of slender workpieces.**
- **With sintered chipbreakers— a guarantee of reliability even with the small nose angle involved.**



See these new Sandvik tools demonstrated on Stand 3209 Hall 3, Brussels Fair, Sept. 3rd-12th

SANDVIK SWEDISH STEELS LTD.

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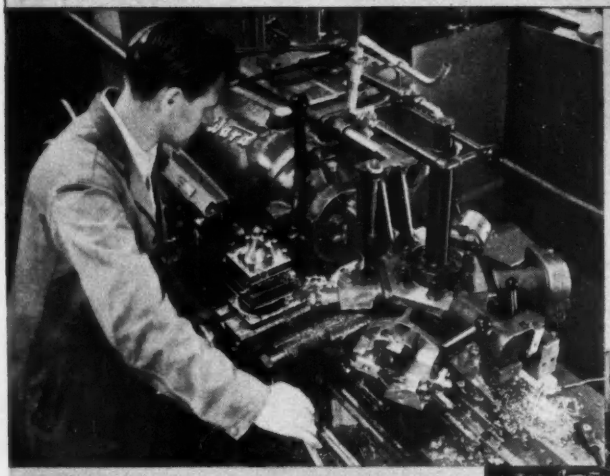
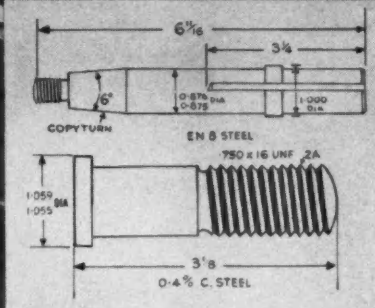
For Maximum Production

Ward 'D S'

DOUBLE-SLIDE CAPSTAN LATHES





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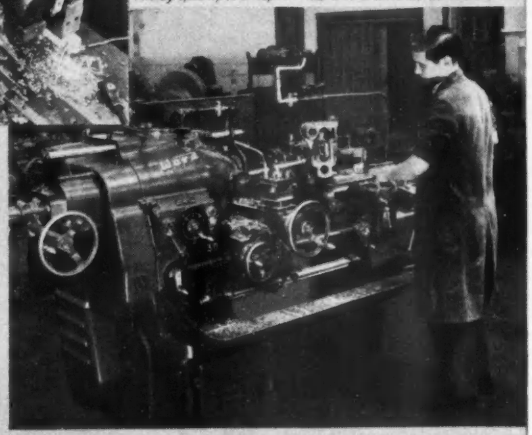
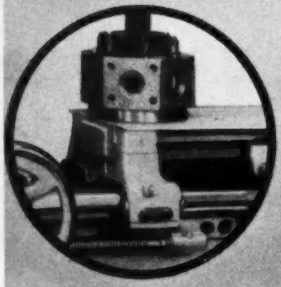


The New DOUBLE-SLIDE allows heavier work with higher rates of removal and provides

Greater Rigidity and Accuracy



Throughout the whole of its forward movement, the hexagonal turret is supported underneath by a sliding bridge which is in direct contact with the bed on all its working surface. This ensures correct alignment at all times, whatever weight of tools the turret carries.

SIZES AVAILABLE	2DS	3DS	7DS
Bar Capacity with Standard Spindle	1¼ in	1½ in	2 in
with oversize Spindle	1½ in	2 in	2½ in

'PRELECTOR' No. 7 Combination Turret Lathe with Preselective speed-changing.

COMBINATION TURRET LATHES with capacities up to 3⅝ in. swing over bed

1¼ in. to 2½ in. 'D-S' DOUBLE-SLIDE Capstan Lathes for heavier accurate work.

Tools, Toolholders, Chucks and Accessories for Capstan and Turret Lathes.

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BRITISH MACHINE TOOL MAKERS ASSOC. ABMTM LTD

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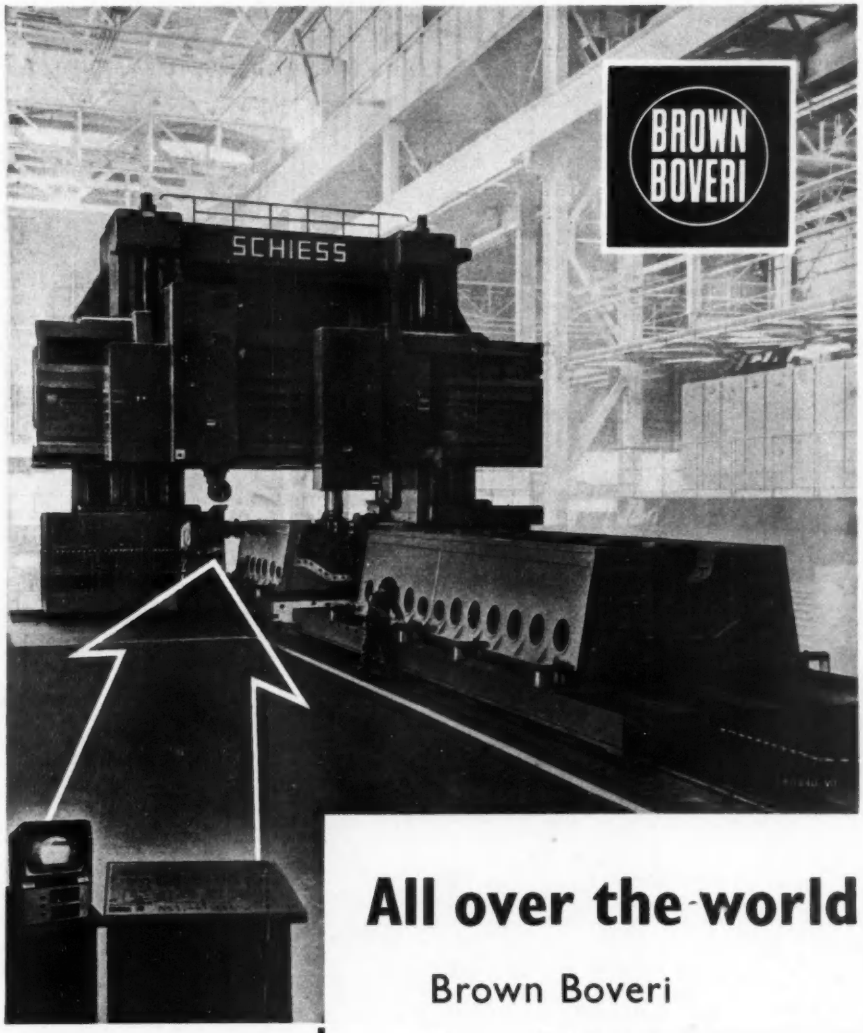


This large milling machine weighing 900t and with a frame 46m long stands in the workshops of Sulzer Bros., Winterthur, Switzerland, and is the largest of its kind in the world. It contains 140 electric motors with a total input rating of about 1100 kW all of which were supplied by Brown Boveri.
The novel design of the control desk (inset) with a coloured mimic diagram allows the machine to be controlled with ease, despite the large number of drives.

All over the world

Brown Boveri
Electric Drives
for Machine Tools

from the extremely simple to
the completely automatic

BROWN BOVERI

BROWN, BOVERI & CO., LTD., BADEN - SWITZERLAND
Representatives in most countries

PRINGS THE WORLD HAS LEARNED TO TRUST

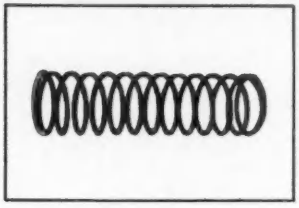
Salter Springs will give you continuous, trouble-free performance. Their reliability is founded on craftsmanship and quality control backed by 200 years of experience.

Cheaper springs could fail, causing costly breakdowns in your production and loss of income to your company.

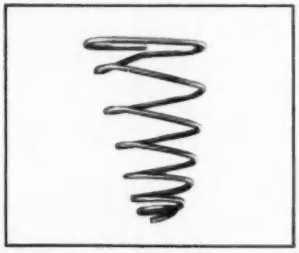
Salter will devise, advise and experiment in order to produce the perfect spring for the job, whatever the problem, the purpose, the size or the shape.

Salter springs are tested and retested to the highest possible standards of accuracy and endurance — you can stake your reputation on Salter reliability.

SALTER



TWO CENTURIES' EXPERIENCE WITH TOMORROW IN MIND



GEO. SALTER & CO. LTD., WEST BROMWICH, ENGLAND. Established 1760.

GRINDING DIESEL TRANSMISSION GEARS FOR THE TRACTION DIVISION OF ASSOCIATED ELECTRICAL INDUSTRIES LTD.

Diesel-Electric Locomotive transmission gears are shown being ground at our Shirley Works for the Traction Division of Associated Electrical Industries Limited.

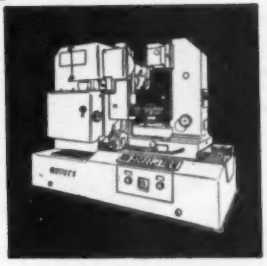
The new GL 48 machine, as illustrated, allows gears to 48" diameter by 12" face width to be ground to a coarse pitch of 1·75 D.P.

Write for our latest literature on the GL 48 Gear Grinding Machine.

Comprehensive Gear Grinding Service

Gears manufactured and ground complete

Makers of the Orcutt Range of Gear and Spline Grinding Machines



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700 to 0 r.p.m.
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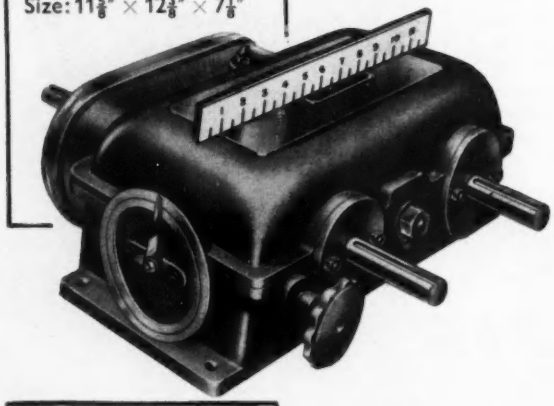
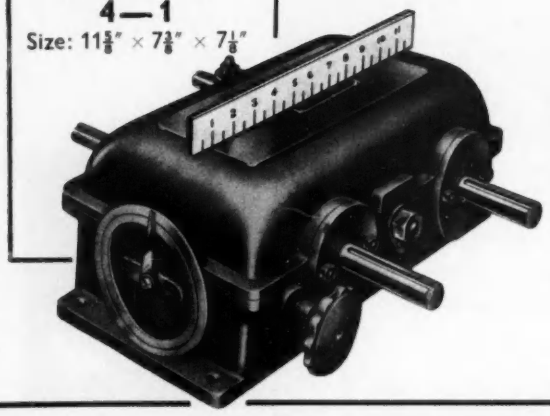


TYPE OA
SPEED RANGE
4—1
Size: $11\frac{5}{8}$" × $7\frac{3}{8}$" × $7\frac{1}{8}$"

The twelve inch rule indicates relative dimensions.



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INTERNAL GRINDER

for production of Injectors
and high-precision components

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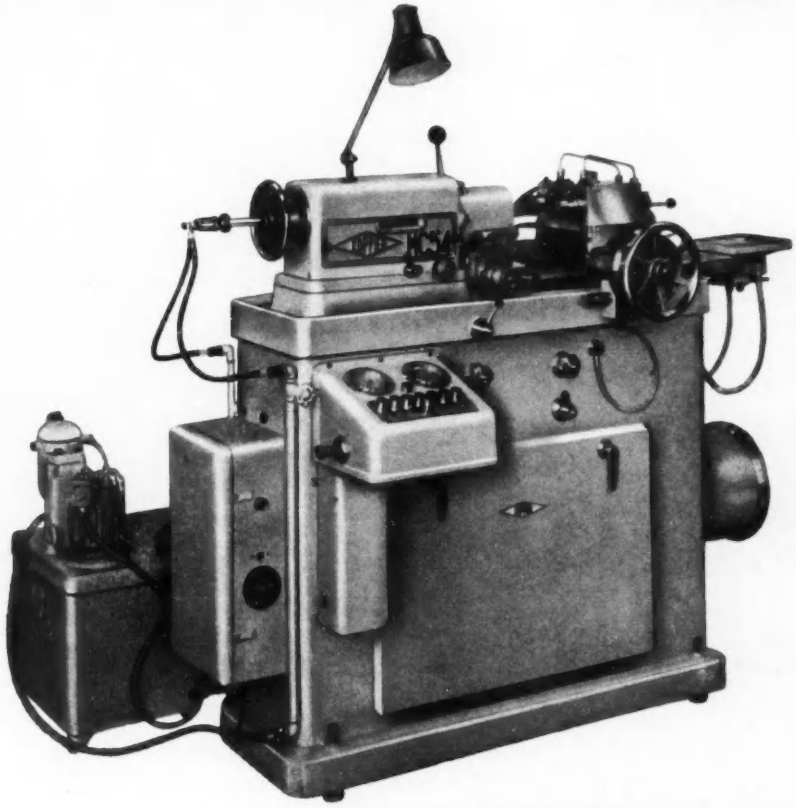

TECHNICAL CHARACTERISTICS

Internal grinder for holes of 1 to 20 mm diameter in high-hardness alloys, e.g., gauges, dies, etc. Spindle speeds from 60,000 to 140,000 rpm.— Quick adjustment for control of diameters, with automatic feed of the spindle head: automatic stop — Supply voltage according to requirements. Weight of complete Grinder approx. 750 kg.

CONSTRUCTIONAL FEATURES

Grinder specially designed for the mass production of injectors of any type for the internal grinding of gauges and dies in tungsten, carbide and other alloys, for work requiring a very high degree of precision of the order of 0·0003 mm both in roundness and centricity with surface micro-roughness of 0·00025 mm. Perfectly smooth surfaces are obtained, in view of the complete absence of harmful vibrations The perfect finish of the surfaces, combined with exact geometrical shape, is always assured by the M.C.54 Grinder fitted with patented M.C.52 "Turbo Spindles", with automatic take-up of bearing play, oil-mist lubrication, and other features introduced into its construction. All the adjustments of the individual members of the machine are hydraulically controlled. The machine is fitted with turbine-driven spindles of very high rotational speeds, from a minimum of 60,000 to a maximum of 140,000 rpm; one of these spindles serves to grind cylindrical parts and the other conical parts (e.g. injector and valve seats) according to requirements.

The rotating spindle unit of the M.C.52 "Turbo Spindles" employ a small turbine and the hydraulic system adopted, as compared with electrically-driven spindles, affords numerous advantages, including the following :—

- **simplicity of construction.**
- **variable speed range between the limits required, depending upon the internal dimensions to be ground.**
- **normal operating speed : 120,000 — 130,000 rpm.**
- **speed variation between full and no load about 3-4 per cent.**
- **extremely simple automatic lubrication, without the need for cooling equipment.**
- **possibility of grinding diameters from 1 to 20 mm.**
- **automatic take-up of bearing play by means of a patented device which guarantees longer life to the bearings.**
- **operating life of the spindle at least 800 working hours guaranteed.**
- **high-precision grinding and finishing of the parts.**

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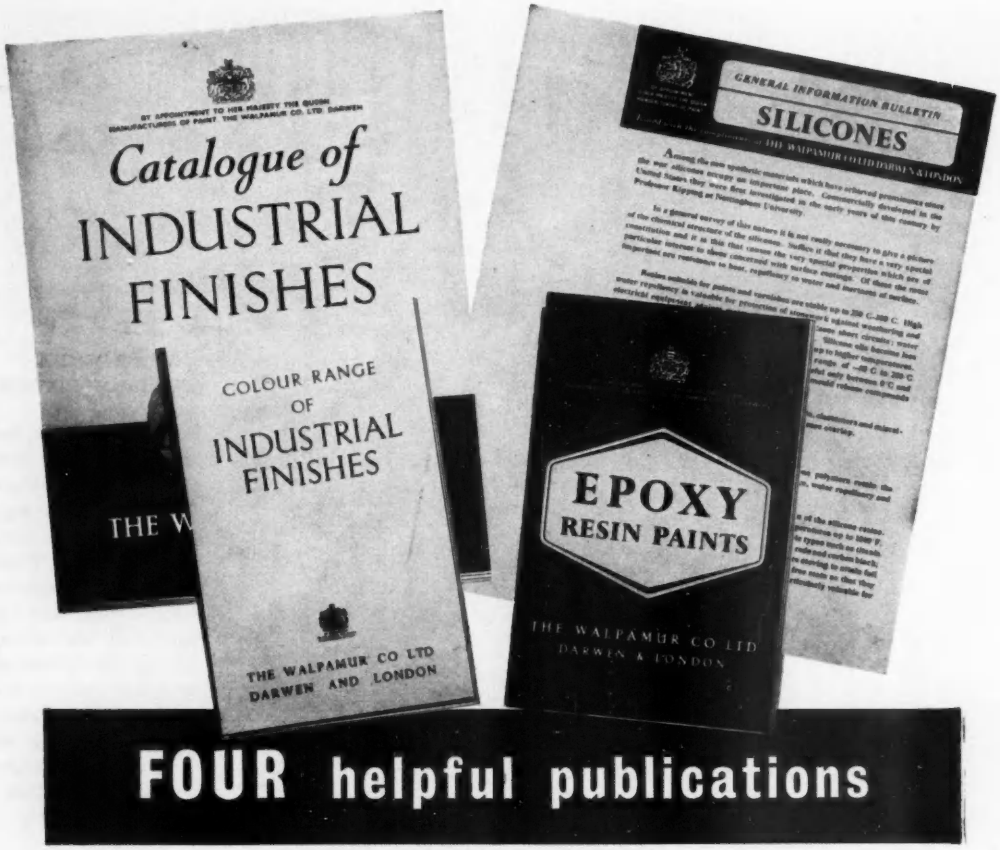

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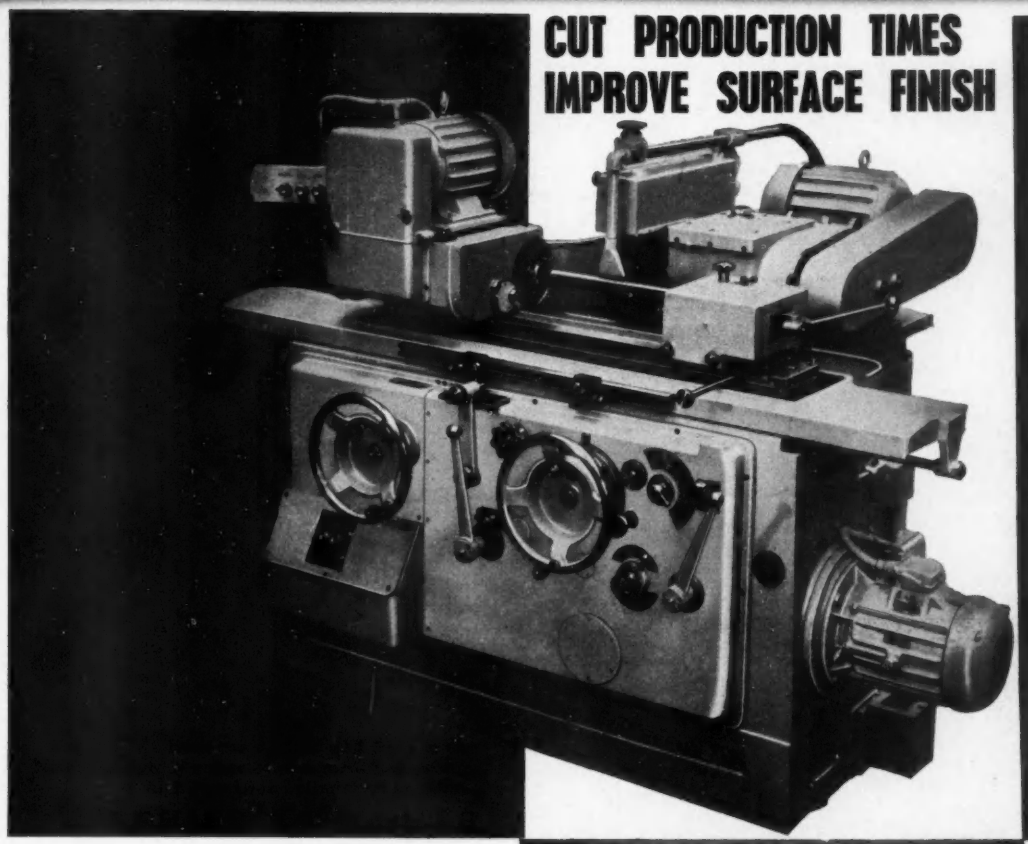
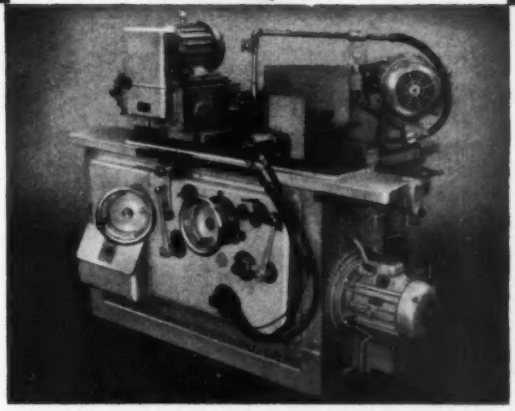


Features:

- Capacity between centres—18 inches (18 or 24 inches in type L6), maximum grinding diameter—6 inches.
- Compactness—self-contained unit reduces space requirements to a minimum.
- Fully hydraulic operation of wheelhead and table movement.
- Unit construction of hydraulic control panel simplifies operation and aids servicing.
- Built to give toolroom tolerances and superior component finish under exacting production conditions.
- Hydraulic wheelhead—mounted dresser or internal grinding head included in wide range of optional equipment.



SERIES L6
Angle Head Grinder

This high production machine with 45° angle head for grinding an external diameter and adjacent face of a component from one setting has an extensive field of application in modern engineering practice. Built to the same sturdy proportions as the plain grinder illustrated above and with similar features, it is offered with a capacity of 18 inches or 24 inches between centres and will grind components up to 6 inches diameter.

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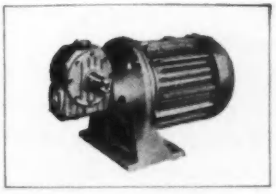
Please write for catalogue V.60 which gives further technical information.



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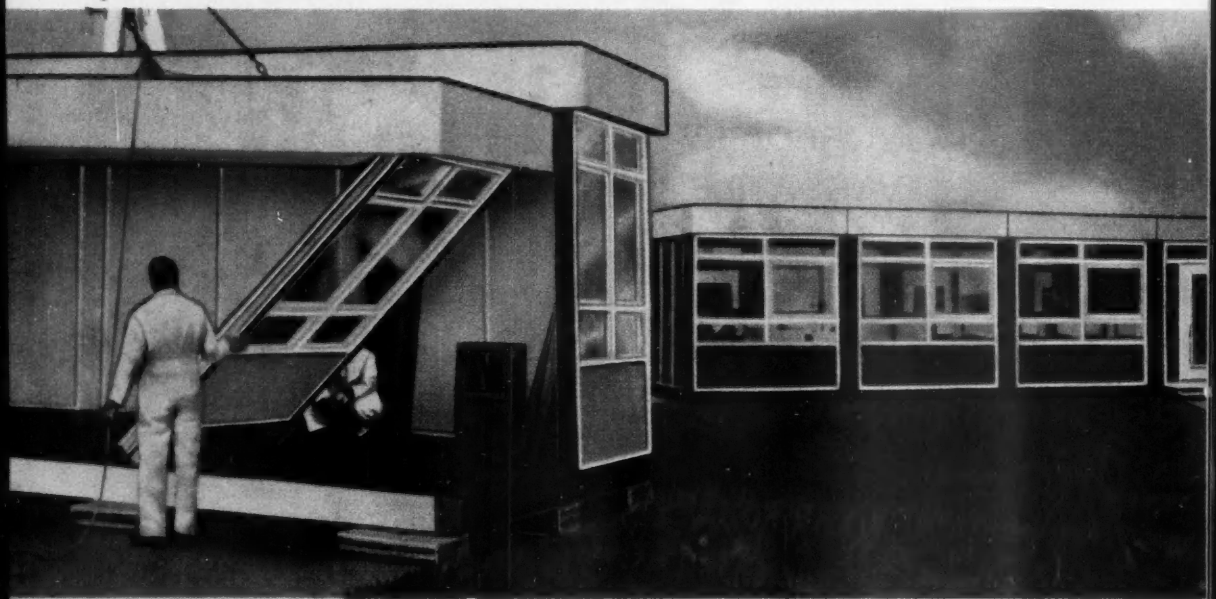

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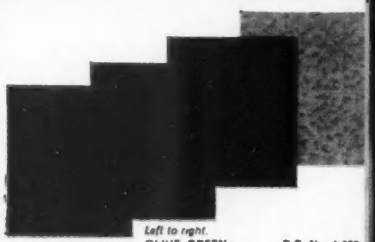

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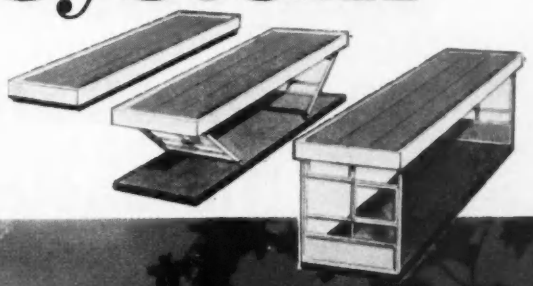

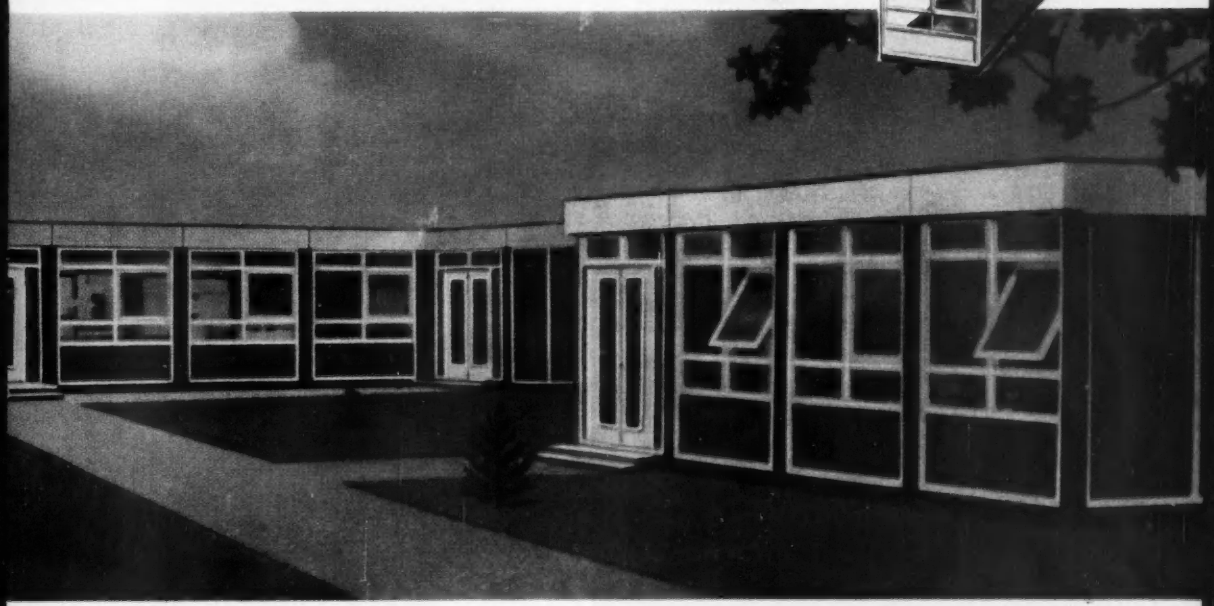

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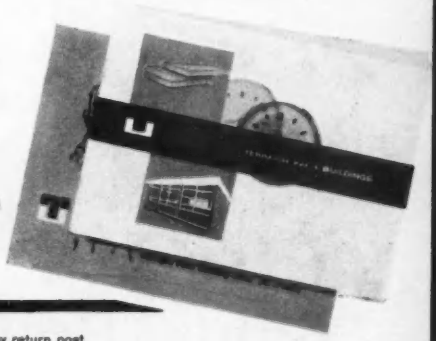

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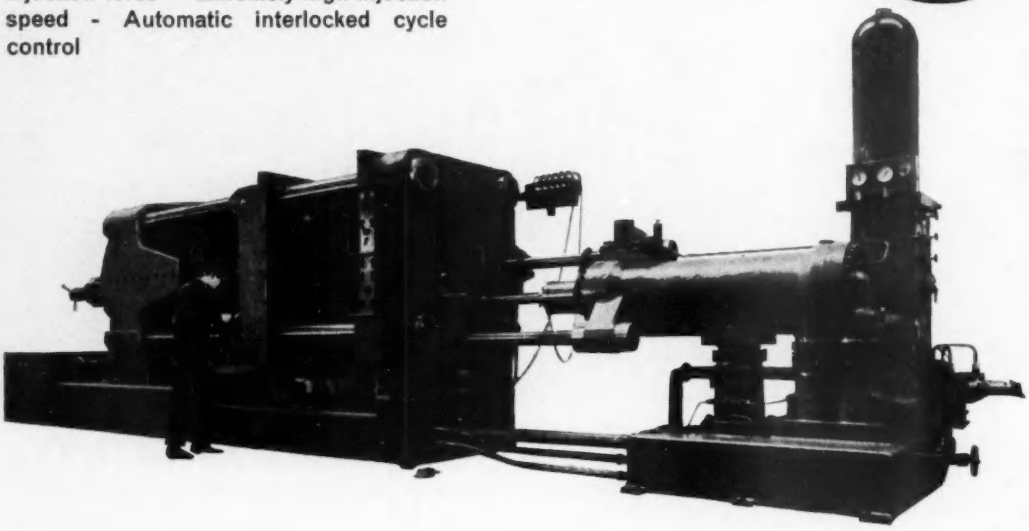

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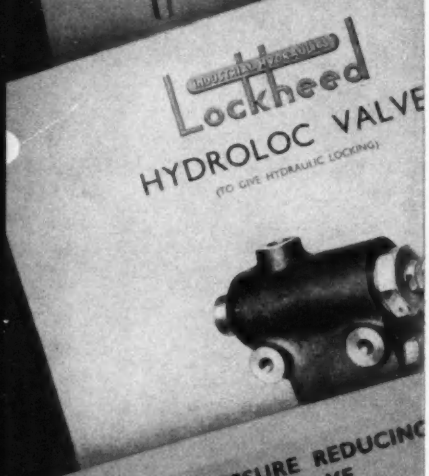

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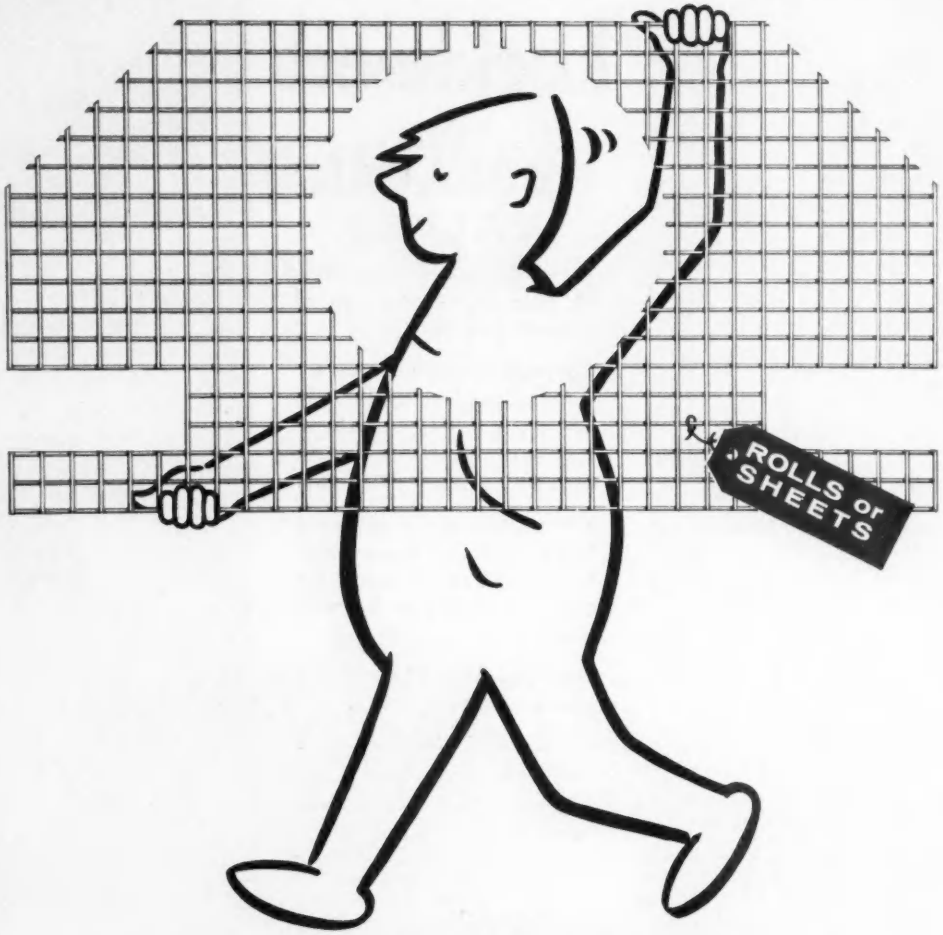

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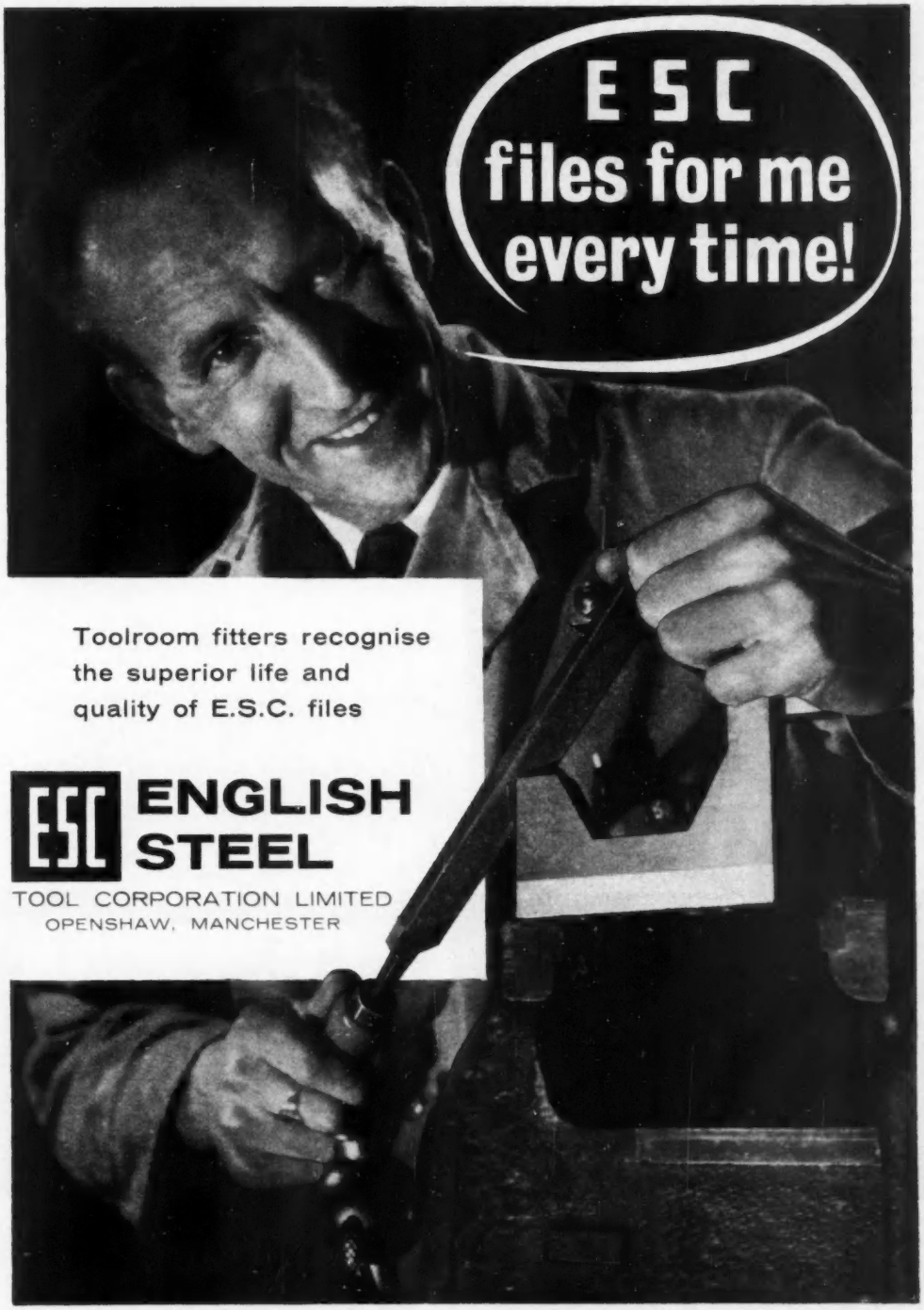
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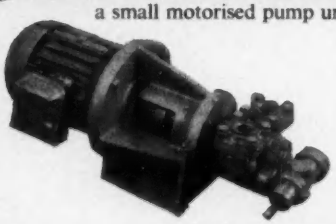

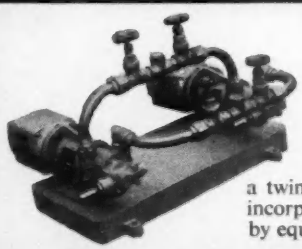

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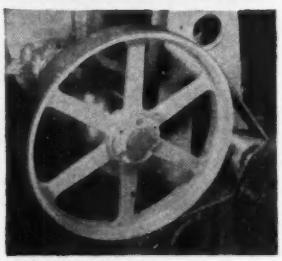

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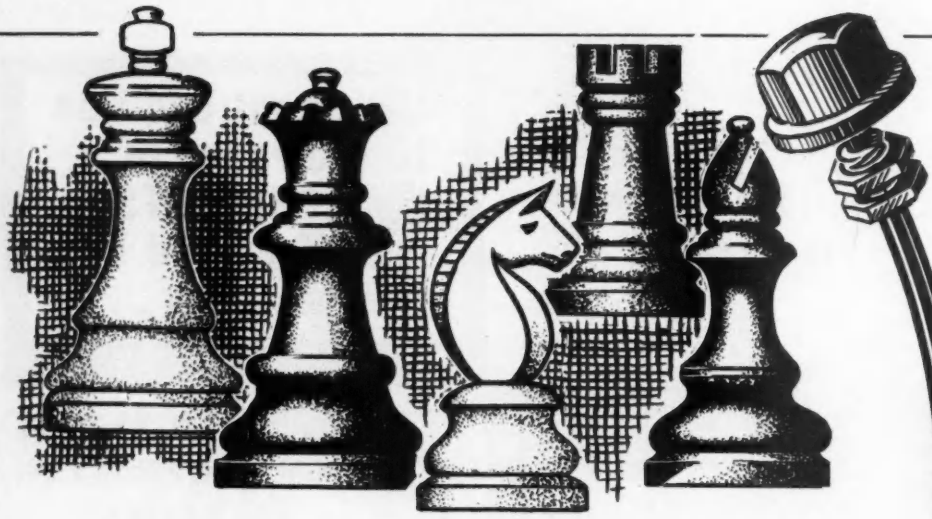

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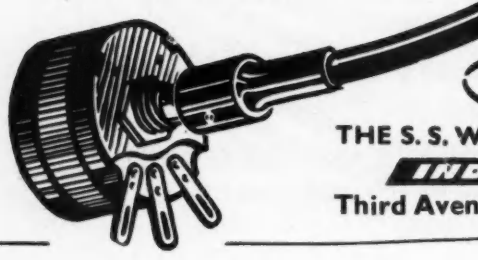

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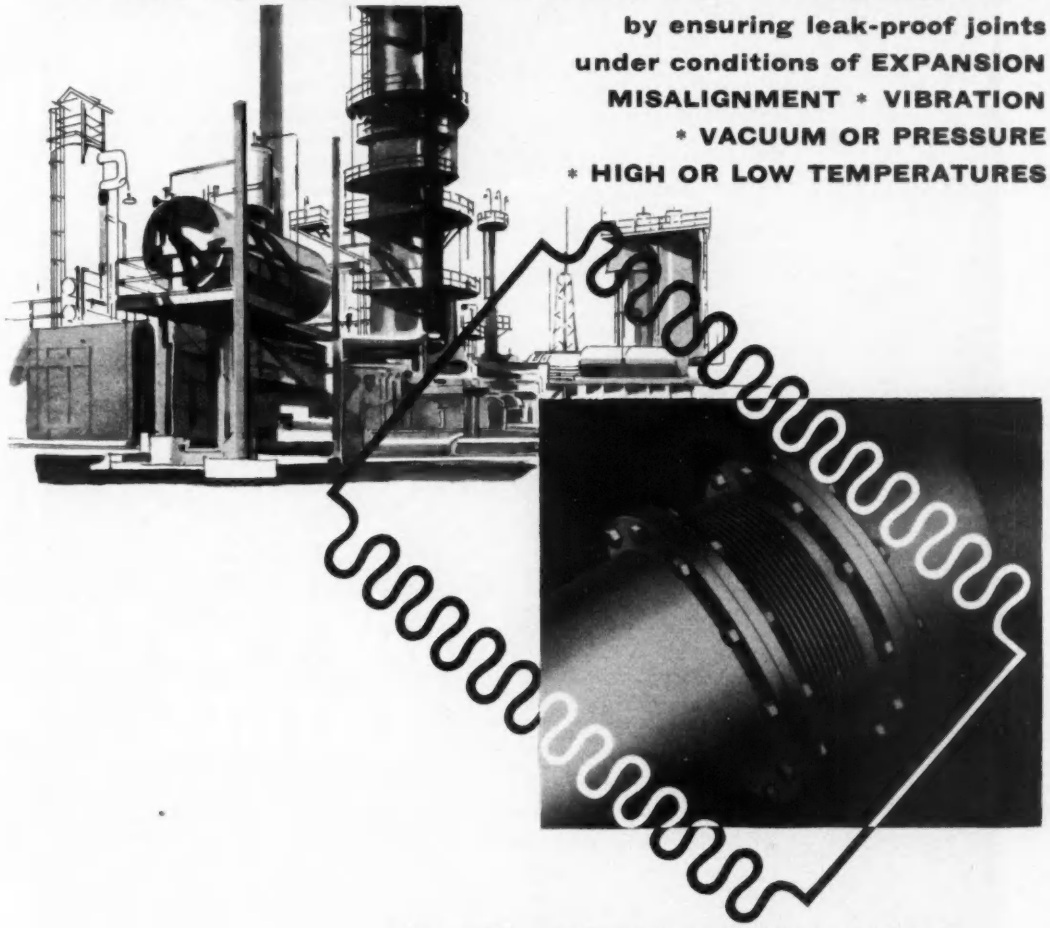

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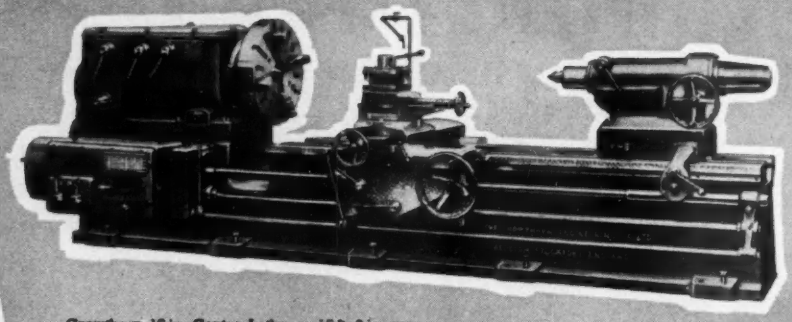

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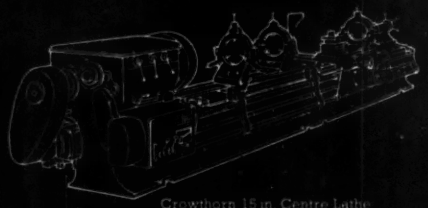

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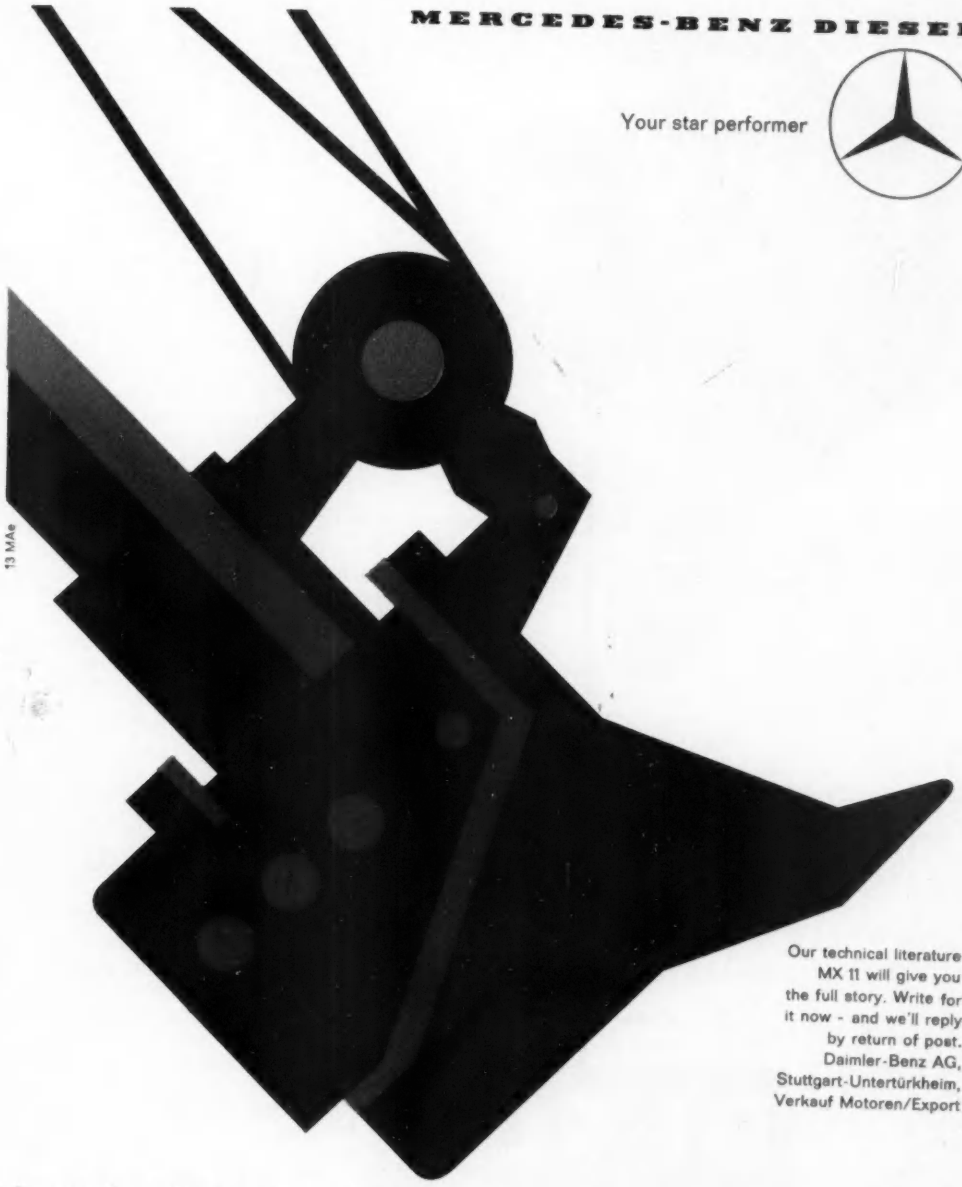

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A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *FLEXIBLE ANODIC COATINGS ON ALUMINIUM*

In the manufacture of aluminium products suitable for such applications as electric-motor and transformer windings, it is essential that anodic insulating coatings possess not only good dielectric properties, but also a high degree of flexibility. In this connection, various methods of imparting improved flexibility to anodic coatings on aluminium have been proposed, but experience has shown that the resulting coatings do not possess sufficient porosity and resistance to electrical breakdown to meet modern electrical standards, and that anodically coated aluminium which retains its dielectric properties under severe bending has not yet been produced by existing methods.

It has now been discovered, however, that a porous and highly flexible anodic coating on aluminium strip or wire can be obtained by carrying out anodization in a bath containing both a metal halide and an organic dicarboxylic acid. Based on this discovery, a recently patented process for producing such coatings involves the use of a conventional type of anodizing bath, to which has been added from about 0·1 to 10% by weight of the metal halide and at least 0·2% of the organic dicarboxylic acid. The preferred type of bath contains an aqueous solution of sulphuric acid in a concentration between 5 and 7% by weight. Typical metal halides include the chlorides of sodium, potassium, calcium, and lithium, the iodides of potassium and calcium, and sodium bromide, while the organic dicarboxylic acids include oxalic, malonic, succinic, and glutaric acids. A typical anodizing electrolyte is a 17% solution of sulphuric acid, to which has been added about 0·5% of sodium chloride and 2% of oxalic acid. Direct- or alternating-current sources can be used, but direct current has been found preferable, as it enables a high-quality product to be obtained more consistently. Also, lower current densities are required to obtain adequate flexible coatings with direct current than with alternating current, current densities ranging from about 200 to 500 A/sq ft for direct current, and from 400 to 1200 A/sq ft for alternating current. The temperature of the electrolyte is not critical, a range between 65 and 95°F producing good results. The anodizing time is generally of the order of 30 sec.

It is stated that coatings produced by this process are extremely adherent, and the strip or wire can be bent to radii of from four to five times its thickness without adversely affecting the dielectric properties of the coating. By comparison, standard anodic procedures yield coatings which lose their entire dielectric strength after the strip or wire is bent through a radius of fifteen times its thickness.

From *Brit. Pat. Spec.* 875,396.
Reynolds Metals Company, Richmond, Va., U.S.A.

● *TRANSFORMER WINDINGS OF ALUMINIUM FOIL*

As distinct from transformer windings consisting of round wire, where one wire is in contact with those around it only at points, the use of flat aluminium foil enables one turn to be in complete contact with the next, permitting the total area occupied by the winding to be reduced to a minimum. Despite the resulting advantages of reducing cost and weight without increasing size, manufacturers have not adopted aluminium foil on a wide basis. According to a recent report, it is believed that the reason is the supposed cost of converting the plant to the use of foil. In this connection, it is pointed out that, although machines for winding copper-wire transformer coils cannot be used for producing aluminium-foil coils, machines for the latter purpose can be much simpler in construction and hence less expensive. Thus, the foil machine requires no traversing mechanism such as is required for winding wire in layers, and a winding of aluminium foil can be made much more quickly.

Various methods of insulating one turn from another in the construction of a foil-type transformer are possible. One method comprises winding the foil with a paper or film insulator, while another involves anodizing, which has the advantage that the anodic coating can withstand high temperatures and also that, because it is so thin, it enables the size of the coil to be reduced to a minimum. A third method, now under investigation, uses inter-turn insulation, in which a resin or lacquer of the two-stage type is applied to the foil and is then dried off sufficiently to allow the foil to be reeled up and slit into reels of suitable width. Another point to be considered is the best way to make the necessary electrical connections to the windings. Various techniques are possible, one of the most effective of joining being by

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cold pressure-welding, necessitating only a simple hand-tool, which can, if desired, be adapted to mechanical use for large production.

Bearing in mind that the technical difficulties involved in the production of aluminium-foil transformer windings are not as great as generally supposed, and that they possess definite advantages in cost and technical performance, the report concludes that the present resistance to their more widespread adoption will disappear as manufacturers add to or replace existing equipment.

From *Aluminium News*, Canada, July 1961, p. 7.

● *WELDING AND JOINING BY MEANS OF EXPLOSIVES*

Within the past few years, explosive-forming has become a familiar and useful process. According to a recent report, research indicates that it is now possible to utilize explosive energy in two other processes, i.e., welding and joining, and, although the work so far performed has been limited in scope, the potential of explosive welding and joining is well established.

An explosive charge can be used to accomplish welding either by subjecting the bond interface to a very high normal force or by causing a sudden shear between the two surfaces under pressure. A convenient method of carrying out the explosive-welding process is to project the two pieces so that they impact at high velocity; in this way, plastic deformation is virtually certain, and it is possible to control the shear components by the geometrical aspects of the collision. In practice, the two pieces of metal are cleaned and placed in parallel planes, slightly separated from each other. The appropriate amounts of explosive in sheet form are then placed on the outside surface of each piece and are detonated simultaneously. As a result, the two pieces of metal are projected towards each other and collide, and, if the amount of explosive and the spacing have been correctly selected, the pieces will weld together. A useful phenomenon generally taking place during the explosion is the eruption of microscopic swirls or jets on the interface surfaces, contributing greatly to weld strength by their interlocking nature. Explosive welding can be considered a form of cold welding. Because only the local interface region reaches welding temperature, the effects of heat treatment should not be lost, and shrinkage problems should be at a minimum. However, because the process is still in the early research stages, insufficient quantitative data are available regarding these factors, though enough is known to indicate that the process is very practical.

Explosive joining can be distinguished from explosive welding by the nature of the bond. Thus, explosive welding results in a fused interlocking bond, whereas explosive joining provides a frictional or mechanical bond. Although simple friction joints can be made in this way, scoring or knurling will contribute appreciably to joint strength by creating a keying effect that increases the forces resisting separation. Similarly, a mating corrugation technique eliminates the relationship between joint strength and the coefficient of friction, making joint strength entirely dependent on the physical properties of the material being joined. Relatively simple tooling is required for these joints, which could easily be fabricated by enclosing the two ends in an exterior die and detonating an explosive charge in the interior, the explosive being contained in a plastic bag full of water, so as to limit the area of application.

From *The Tool and Manufacturing Engineer*, U.S.A., July 1961, pp. 75–78.

● *TITANIUM ALLOYS WITH IMPROVED DUCTILITY*

In the fabrication of titanium alloys of the alpha type or of the alpha + beta type, it is sometimes necessary to heat these alloys to a temperature in the beta field, resulting in a loss of ductility, even after a subsequent annealing operation. Moreover, the alloys are found to have a coarse-grained fracture, and these effects persist through subsequent heat treatments. It is, of course, true that the ductility of these alloys, after heating in the beta field, can be restored and a coarse-grained fracture can be produced by hot-working, e.g., forging, the alloy at a temperature in the alpha + beta field to bring about a considerable reduction in area, such as 50%. However, hot-working in the alpha + beta field requires much more power than hot-working in the beta field and, in any case, does not permit such large reductions to be made.

It has now been found that, by incorporating small amounts of boron in titanium-base alloys of the alpha type or of the alpha + beta type, it is possible to heat them to temperatures in the beta-phase field without serious loss of ductility after subsequent annealing and without any serious development of coarse-grained fracture. This improvement in ductility is also found after solution treatment and ageing. The addition of boron can be made to titanium alloys of the alpha type or of the alpha + beta type containing up to 15% molybdenum, up to 2·5% copper, up to 10% aluminium, or up to 12% manganese, or up to 10% aluminium in combination with up to 12% manganese, up to 10% zirconium, or up to 20% vanadium. The beneficial effects of the boron additions act over a comparatively small range, i.e., between 0·005 and 0·5% amounts of less than 0·1% being especially

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advantageous. If the boron content exceeds 0·5%, the ductility values after heating into the beta field deteriorate and at 0·9% are low. In addition to effecting considerable improvements in ductility after heating in the beta field, boron has a slight grain-refining effect, and also results in a reduction (by up to about 100°C) in the minimum forging temperature, i.e., the lowest temperature at which forging can be carried out without cracking. Some slight improvement in the tensile strength and the proof strength of these alloys after heating in the beta field has also been found when boron is present, this improvement being rather greater in the case of the alpha + beta alloys than in the alpha alloys. As far as can be judged, the addition of boron neither improves nor adversely affects the creep properties of the alloys.

From *Brit. Pat. Spec.* 873,774.
Imperial Chemical Industries Ltd., London, England.

● ***THERMOCOUPLES FOR ULTRA-HIGH TEMPERATURES***

Recent developments in nuclear science and space technology have focused attention on the need for accurate thermal sensing devices capable of operating reliably at temperatures between 3000 and 5000°F, or even higher. Recently, two new noble-metal combinations for thermocouples have been found to hold considerable promise for certain applications involving temperatures over 3000°F. One of these is a modified version of the platinum-rhodium type, and consists of a platinum-30% rhodium/platinum-6% rhodium combination. With the elimination of the pure platinum wire from the couple, the thermal e.m.f. stability is markedly improved, but there is a considerable sacrifice of thermoelectric power. The second noble-metal thermocouple employs a pure iridium/iridium-rhodium combination, the rhodium content being 40, 50, or 60%. Although the melting points of both these noble-metal types of thermocouple exceed 4000°F, their maximum useful limit in an oxidizing atmosphere is probably about 3700°F.

To meet the requirements for measuring temperatures of 4000°F and higher, the choice of materials for conventional wire thermocouples is limited to four refractory metals, i.e., tungsten (M.P. = 6200°F), rhenium (M.P. = 5800°F), tantalum (M.P. = 5400°F), and molybdenum (M.P. = 4800°F). From the results of preliminary research into the basic thermoelectric properties of the different combinations possible with these four unalloyed elements, it was concluded that the tungsten-rhenium combination possessed the best thermoelectric properties at high-temperatures. However, this combination has the disadvantage that thermoelectric power drops gradually at temperatures above 4000°F and the ductile-brittle transition of pure tungsten results in poor mechanical stability. As a result, further research has been concentrated primarily on a study of tungsten alloys containing up to 30% rhenium (alloys containing more than 30% rhenium are difficult to fabricate). The results of this research have indicated that a tungsten/tungsten-26% rhenium combination would be the most desirable for ultra-high-temperature measurements, as this thermocouple generates a high e.m.f. which remains relatively linear up to at least 5000°F. It should be appreciated, however, that the usefulness of this combination is limited in practice by factors other than inherent thermoelectric properties, one of which is the lack of adequate insulation, imposing a present limitation of 4200°F. With better heat insulators, however, it is expected that the range of this combination will eventually be increased to about 5000°F, though it must be admitted that much work remains to be done before this limit can be applied with full confidence.

From *Metal Progress*, U.S.A.,
July 1961, pp. 73–76.

● ***HIGH-TEMPERATURE BURNER WITH A STABLE FLAME***

Conventional methods of stabilizing the main flame of a burner generally require the use of an auxiliary feed-pipe and do not make it possible to obtain sufficient stability of the flame, except in a narrow range of concentrations of the combustible and combustion-sustaining components of the burning mixture. To obviate this disadvantage, a new design of burner provides for flame stability at the nozzle exit as the result of a sudden increase in entropy, i.e., a sudden increase in pressure and temperature and a reduction in speed during an adiabatic expansion of the components of the burning mixture. Essentially, this is achieved by designing the burner in such a way that a shock wave appears in a stream of fluid flowing at a supersonic speed.

For this purpose, the new high-temperature burner comprises two coaxial pipes for feeding the fuel and the combustion-sustaining agent respectively, the inner pipe terminating at or a few millimetres beyond the throttled section of a Venturi tube fitted at the outer end of the pipe surrounding the inner pipe. The divergent section of the Venturi tube has a very smooth inner surface and is of considerable length, permitting the fluid to expand to below ambient pressure, while the inner surface of the divergent section is provided near its output end with a discontinuity adapted to produce a shock wave. On the downstream side of the shock wave, the pressure increases and, at the same time, the speed drops to a value lower than the speed of

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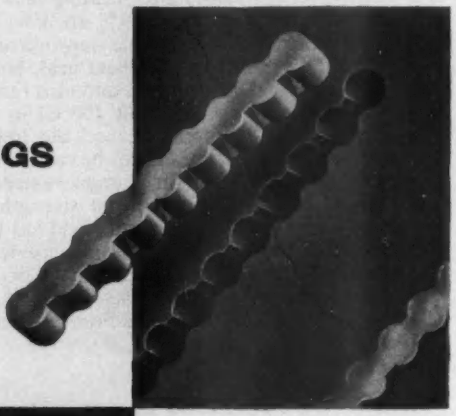

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sound, so that conditions for stable burning are obtained in the zone adjacent to the wall of the Venturi when using a liquid fuel. In the case of a gaseous fuel, the mixture of the fuel with the combustion-supporting medium is perfectly homogeneous and the mixture is ignited throughout the surface of the shock wave, even along the axis of the burner. To produce the shock wave, it is necessary for a certain section of the corresponding plane of the shock wave to be fed with a homogeneous fluid, so that the fuel should not reach the wall of the Venturi. Consequently, in the case of a liquid fuel, the fuel pipe should be of small diameter with reference to the neck or throttled section of the Venturi tube, and the fuel should be injected at a high speed, so as not to be atomized too speedily. With a burner of this type, there is no pilot flame and no auxiliary feed-pipe, distinguishing it from existing types, both with respect to construction and operation.

From *Brit. Pat. Spec.* 873,423.
Inst. de Rech. de la Sidérurgie Française, St. Germain-en-Laye.

● *HIGH-DENSITY ALLOYS FOR ELECTRICAL CONTACTS*

Containing at least 90% by weight of tungsten and silver, of which from 30 to 60% is tungsten, from 0·1 to 5% of copper or iron, and from 0·1 to 5% of nickel or cobalt, a new range of composite high-density alloys for use in electrical contacts has a density amounting to about 95% of the theoretical density and is capable of withstanding high electrical loads. The high density is obtained by the liquid phase formed by the copper or iron and the nickel or cobalt during sintering, the tungsten being soluble in this phase in a proportion of more than 20%. On cooling, the solubility of the tungsten decreases considerably, resulting in its precipitation. The tungsten is embedded in the form of round particles in the silver, which still contains some copper (or iron), nickel (or cobalt), and tungsten, the contact material thus obtained being substantially pore-free.

The content of tungsten is varied in accordance with particular requirements, typical compositions containing 50% W, 40% Ag, 5% Cu, and 5% Ni, or 54% W, 44% Ag, 1% Cu, and 1% Ni or Co. After pressing an intimate mixture of the metal powders at a pressure of about 1000 kg/cm², sintering is carried out in an inert or protective atmosphere, e.g., hydrogen, at from 1050 to 1100°C for 1 hr. If the alloy is to be used for contacts in vacuum-switches, sintering normally takes place in a high vacuum, preferably less than 10^{-2} mm Hg. As an example of the application of the process, if an intimate mixture of 64% W, 34% Ag, 1% Fe, and 1% Ni is pressed at 1000 kg/cm² and sintered for 1 hr at 1100°C, the pressing density rises from 8·0 to 13·5 gm/cm³, corresponding to a packing degree of 92%. If required, the composite metal can then be compacted substantially to the theoretical value of about 14·7 gm/cm³ by subsequent cold-pressing.

From *Brit. Pat. Spec.* 874,457.
Siemens-Schuckertwerke A.G., Erlangen, Germany.

● *SIMPLE AUTOMATIC SPEED-CONTROL SYSTEM FOR A.C. COMMUTATOR MOTORS*

Electronic methods of controlling the speed of a.c. commutator motors are efficient, but are often complicated and expensive. On the other hand, other existing arrangements, of the type involving the use of a tacho-generator and a polarized relay for controlling a servo-motor which drives the regulator of the a.c. motor, are admittedly simpler, but generally have a by no means satisfactory performance and do not meet all drive requirements. To overcome the deficiences of speed-control systems of the latter type, an improved design has been developed and is claimed not only to retain all the advantages of simplicity, but also to ensure reliable and satisfactory performance.

In the new system, the speed of the a.c. commutator motor is maintained automatically at the desired value by the displacement of a control device driven by a servo-motor which is controlled by a polarized relay. This relay responds when a voltage derived from a motor-driven tacho-generator deviates from a reference voltage, a simple correction circuit being connected in series or in parallel to the input circuit of the relay controlling the servo-motor. The correction circuit is used to control an electromagnet, which selects the required speed ratio between the servo-motor and the control device of the commutator motor. The correction circuit consists of resistances and capacitances, and responds to the value of the error voltage and to its rate of change. A battery is provided for supplying current for the electromagnet and the correction circuit. The reference voltage is derived from another battery, the value of this voltage, and hence the desired regulated speed of the motor, being controlled by the slider of a potentiometer.

From *Brit. Pat. Spec.* 875,312.
Zavody V. I. Lenina Plzen, Narodni Podnik, Czechoslovakia.

Readers desiring further information on any developments reported in THE BLUE PAGES are invited to write to the Editor. Copies of the full specifications of any British patents mentioned, which are published by courtesy of H.M. Stationery Office, should be obtained from the Patent Office, 25 Southampton Buildings, Chancery Lane, London, W.C.2. Price 3s. 6d. each.

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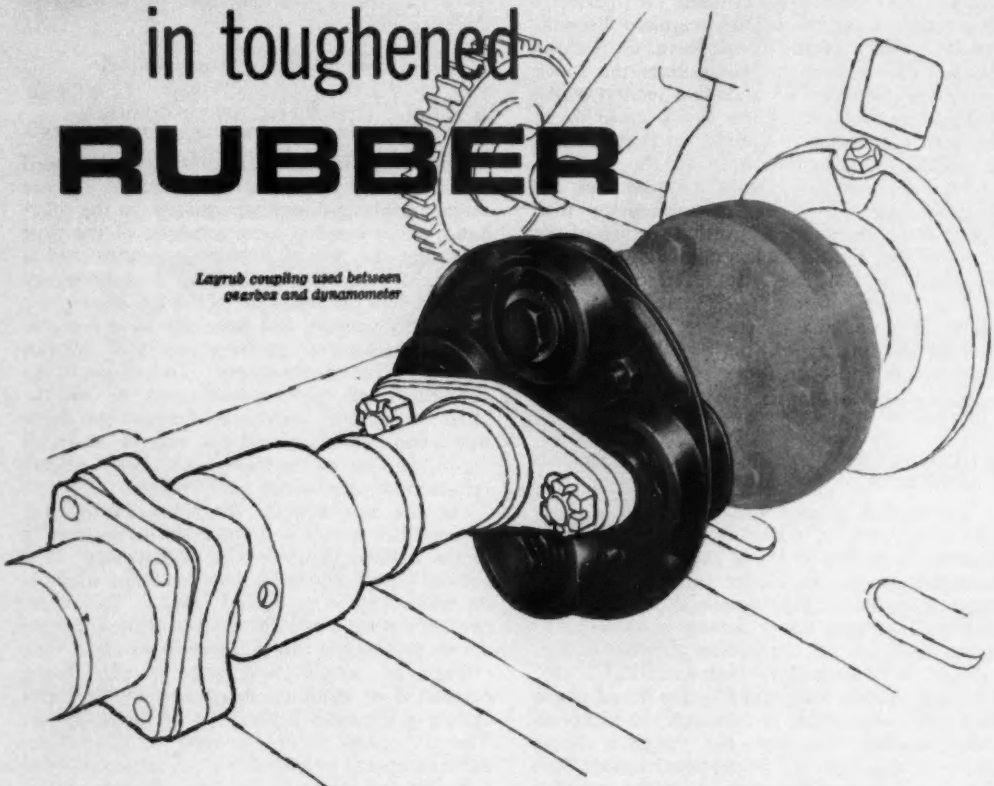

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A World Review of DESIGN & PRODUCTION — RESEARCH & DEVELOPMENT

VOL. XXII No. 9 SEPTEMBER, 1961

Injection-Moulded Ceramics

By R. L. RANDOLPH

From *Materials in Design Engineering*, U.S.A., Vol. 54, No. 2, August 1961, pp. 10–12, 6 illustrations.

ALTHOUGH the injection-moulding of ceramics is not an inherently new technique (sparking-plug insulators, for instance, were produced in this way some years ago), it is believed that a variant of the technique has now made it possible for the first time to produce a wide range of ceramic compositions by this method economically and in larger quantities in other than relatively simple shapes. As an example, thread guides for textile machines used to be machined one at a time from titanium dioxide, whereas fourteen guides are now injection-moulded automatically and at high speed in one shot. The only subsequent work consists of one machining operation, firing, and drum finishing, multiple machining and hand-polishing being eliminated entirely.

The advantages of the injection-moulding process for ceramics can be summarized as follows:—

(1) Automatic moulding in multi-cavity moulds can substantially reduce the cost per part.

(2) The method of filling the mould permits the production of parts more complex in shape than would be considered economically possible in large quantities by other methods.

(3) Part-to-part reproducibility of dimensions is greater than that obtainable economically by machining; in addition, moulded surfaces are smoother than extruded or machined surfaces.

(4) The injection-moulding process uses mixtures of materials (ceramics, thermoplastics, and oils) which are less sensitive to such process variables as moisture and humidity than the mixes used in traditional dry pressing and extruding; consequently, closer tolerances are possible.

More than a dozen ceramic compositions have been injection-moulded over the past three years with consistent success. These include aluminas, titanium dioxide, forsterite, zircon, spinel, barium titanates, and various alkali-leachable ceramics. These materials can be injection-moulded to meet both mechanical requirements, (for thread guides, appliance parts, nose cones, cores for castings, etc.) as well as electrical and electronic requirements (for radomes, capacitors, switch parts, etc.).

The mixture of ceramic, plastics, and oil used can be varied to control shrinkage, overcome difficult flow problems in moulding thin sections, and improve handling characteristics. There are, however, important limitations to keep in mind. Thus, although a fragile, thin, curved section, such as an aerofoil-shaped core for a jet-engine turbine blade, may be relatively easy to mould, it still must be fired. If the ceramic tends to slump during firing, the part may need special "setters," or supports, in the kiln. Such setters are often costly, as they may be nearly as complex as the part itself.

In designing a part, it should be remembered that the same tapers, parting lines, gate marks and ejector-pin marks encountered with injection-moulded plastics parts are necessary for ceramics. Also, the shrinkage of ceramics during firing is usually much greater than the post-mould shrinkage of plastics. Ceramic shrinkage may range from 2 to 21%, depending on composition. Consequently, ceramic parts cannot be produced to size with moulds designed for thermoplastics.

This shrinkage, as well as other design factors, makes it critical for designers to consult the ceramics moulder in the initial design stages. For example, in general, when the heaviest section of a part exceeds $\frac{1}{4}$ in., the part is difficult to mould and fire properly. Consequently, before freezing the design, it may be desirable to incorporate such compensating features as grooves, holes, or depressions to reduce sections.

On the other hand, parts with sections that are too thin, and parts with deep draws tend to slump during firing. Although no unusual difficulty is experienced in moulding sections as thin as 0·02 in., the shape must either support itself or be externally supported in the kiln. Such thin sections should be limited to 4·5 sq in. or less, to prevent flow problems during moulding.

In carrying out the process, the ceramic materials to be injection-moulded are carefully weighed, mixed, and ball-milled to ensure homogeneity and uniformity of particle size from batch to batch. The ceramic is then combined with thermoplastic resins and oils, carefully selected on the basis of their melting points, molecular weights, and ash contents, and then matched with the particle size and bulk density of the ceramics.

The oils serve a dual purpose, i.e., they lubricate the mix during injection, and they build porosity to permit removal of all volatiles during firing. An orderly sequential volatilization of the non-ceramic ingredients is necessary to prevent distortion of the part during firing. For example, the light oils, which vaporize first, do so slowly, producing a slight porosity that speeds the removal of the next oil to volatilize. The plastics are the last in the chain of volatiles to bake out.

Towards the end, this distillation process is halted to leave a small amount of resin in the part for green strength sufficient for handling, grinding, or machining prior to final firing, which volatilizes all the remaining additives. This process of baking out volatiles may require as long as eight days, depending on the mass of the formed part.

The injection-moulding machines are hopper-fed and automatically controlled by time-cycle relays. The baking-out process takes place in an electrically heated, programme-controlled oven. Final firing is effected in the same kilns used for firing other types of formed ceramic parts. Firing temperatures range from 1200 to 3100°F, depending on the type of ceramic.

The Present Status of Fuel Cells and Batteries

By G. S. Lozier

From *RCA Review*, U.S.A., Vol. 22, No. 2, June 1961, pp. 325-346, 9 illustrations.

This paper discusses the present state of development of fuel cells and batteries as energy sources and energy-storage devices. The various types described are evaluated from a consideration of the energy content of the reactant materials and the basic methods of handling them in electrochemical cells. Regenerative electrochemical cells are also discussed, with emphasis on space applications.

In a fuel cell or battery, direct electrochemical conversion of chemical to electrical energy is essentially isothermal. As a result, the process escapes the Carnot-cycle limitation. The basic thermodynamic relationship between the maximum useful energy available from an electrochemical reaction and the heat content of the system is expressed by the equation

$$\Delta F = \Delta H - T\Delta S \quad \ldots \quad (1)$$

where ΔF is the free-energy change, ΔH is the heat-content change, ΔS is the entropy change, and T is absolute temperature. The maximum electrical energy available from an electrochemical process under reversible conditions is equal to the free-energy change of the reaction; the thermal efficiency η_t under ideal conditions can be expressed as

$$\eta_t = \frac{\Delta F}{\Delta H} = 1 - \frac{T\Delta S}{\Delta H} \quad \ldots \quad (2)$$

Because the maximum thermal efficiency of an electrochemical cell is determined by the sign and magnitude of ΔS, which is usually small under normal operating conditions, a fuel cell or battery which approaches reversibility has a high theoretical thermal efficiency. In practice, this condition is met by cells operated near their theoretical open-circuit voltage.

During battery operation, the electrochemical reaction produces both electrical energy and heat. Deviations from reversibility result from the irreversibility of the electrode reactions and from cell resistances. Although the reaction heat can be used to maintain cell operating temperatures in some systems, it may be necessary to cool the cell in other systems.

Fuel-cell efficiency can also be stated in terms of current, voltage, and free-energy efficiencies. Thus, free-energy efficiency is a measure of an electrochemical cell as an energy converter and may be used in comparing various cell types and constructions. Voltage efficiency is used as a first approximation of the free-energy efficiency when no side reactions or loss of active material exist (i.e., when the current efficiency is 100%). Thermal efficiency is used to compare a fuel cell with an indirect process operating in a thermal cycle between the same initial and final states.

The efficiencies of indirect methods of energy conversion suffer from the unavoidable thermodynamic limitations imposed by a Carnot cycle on processes which convert heat into work. The maximum chemical energy that can be converted into electrical energy by a heat engine under ideal conditions is given by the expression

$$\frac{\Delta H\,(T_H - T_c)}{T_H} \quad \ldots \quad (3)$$

where T_H is the temperature of the heat source of the heat engine and T_c is the temperature of the heat sink of the engine. Under preferred operating conditions, a central power plant would have a Carnot efficiency of approximately 65% and an overall efficiency of approximately 40%. This is the highest efficiency obtained to date for the indirect conversion of chemical to electrical energy.

With regard to other conversion processes under investigation or in use, the fuel cell or battery, involving the direct conversion of chemical to electrical energy, has a thermal efficiency of up to 90%. Petrol engines and diesel engines, in which heat is converted to mechanical energy, have respective maximum thermal efficiencies of 20% and 34%. Thermionic and thermoelectric devices, in which heat is converted to electrical energy, have respective thermal efficiencies of 14% and 7%, while the efficiency of magnetohydrodynamic devices, which also involve conversion of heat to electrical energy, is estimated to be up to 60%.

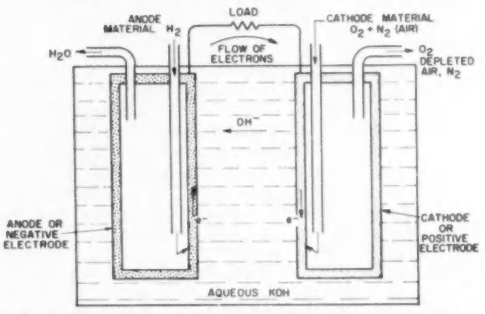

Fig. 1. Electrode reactions and relative flow of ions in a typical hydrogen-oxygen fuel cell with an aqueous solution of potassium hydroxide as the electrolyte.

The basic components of a typical fuel cell and a typical primary cell and their functions are shown in Figs. 1 and 2 respectively. In chemical terms, anode materials are reducing agents which are characterized by the ease with which they give up electrons and are oxidized to a higher oxidation state; cathode materials are oxidizing agents which are characterized by the ease with which they accept electrons and are reduced to a lower oxidation state. Electrical energy is derived from simultaneous oxidation of anode material and reduction of cathode material by electrochemical reaction; electrons flow from the anode electrode through the external circuit to the cathode electrode.

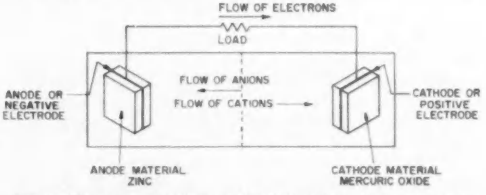

Fig. 2. Electrode reactions and relative flow of ions in a zinc-mercuric oxide primary cell using an aqueous solution of potassium hydroxide as the electrolyte.

TABLE I: FREE ENERGY AND THEORETICAL ENERGY AND OPEN-CIRCUIT VOLTAGE OF VARIOUS HIGH-ENERGY COUPLES

Couple		ΔF at 25°C [kcal/mole]	Theoretical Energy [watt-hr/lb]	E_0 at 25°C [volts]
Anode	Cathode			
Hydrogen	Oxygen	—56·7	1650	1·23
Carbon	Oxygen	—94·3	1120	1·02
Methane	Oxygen	—185·5	1220	1.01
Propane	Oxygen	—508·8	1280	1·10
Decane	Oxygen	—1565·0	1290	1·10
Lithium	Chlorine	—102·0	1260	4·43
Sodium	Oxygen	—144·6	950	3·14
Hydrazine	Oxygen	—143·2	1180	1·56
Methanol	Oxygen	—167·7	1100	1·21
Formaldehyde	Oxygen	—120·0	1010	1·31
Zinc	Oxygen	—75·7	490	1·64

The anode and cathode electrodes make electrical contact with the anode and cathode reactant materials. In the case of non-conducting anode and cathode materials, electrodes usually consist of some form of a porous-carbon or metal matrix. In many electrochemical-cell designs, however, metal-anode material may also serve as the electrode. An electrolyte which permits the flow of ions between the anode and cathode electrodes completes the circuit.

On a weight and volume basis, the available energy from a fuel cell or battery is determined by the basic properties of anode and cathode materials. The two most basic properties are the ampere-hour capacity of the anode and cathode materials, and the cell potential. The ampere-hour values, are directly proportional to the number of faradays per mole involved in the electrochemical reaction, and are inversely proportional to the molecular weight and volume of material.

An examination of the basic properties of anode and cathode materials indicates why many approaches are being considered for the design of electrochemical cells as energy sources. For example, although hydrocarbons are promising materials, they are not electrochemically active in aqueous solutions and need high-temperature molten-salt electrolytes. This high-temperature problem has led to a consideration of redox systems and partially oxygenated carbon compounds as anode materials. These systems may be used in aqueous electrolytes for cells operated at approximately room temperature.

The high-capacity metals either operate considerably below their reversible potentials or are too reactive to be used in aqueous electrolytes. However, an amalgam electrode apparently has solved the latter problem in the case of sodium. It should be noted that the anode materials currently used in electrochemical cells (zinc, cadmium, lead, and iron) have a fairly low capacity. Although magnesium is used in primary cells, it operates considerably below its reversible potential and at current efficiencies of 80% or less.

Because oxygen has a high ampere-hour capacity and is readily available from the atmosphere, the design of electrochemical cells which use air as a cathode material is a desirable goal. In addition, oxygen cathodes make possible the design of invariant fuel cells with a variety of anode materials. Some of the problems associated with air operation are discussed later.

Fluorine, because of handling problems, and chlorine, because of both handling problems and low ampere-hour capacity with respect to oxygen, are not suitable as cathode materials. Oxide and organic cathode materials find most application in conventional primary and secondary cells.

Table I shows the theoretical energy content of some possible anode-cathode combinations, calculated from the free-energy change ΔF of the overall cell reaction at 20°C, and also the standard electrode potential (theoretical open-circuit voltage) E_0 at 25°C. Although many combinations have a high theoretical energy content, only a few can approach these values in practice. The principal reasons why electrochemical cells do not approach the theoretically available energy can be summarized as follows:—

(1) The voltage efficiency of electrodes is never 100% because of the effects of activation, concentration, and ohmic polarization encountered under load conditions.
(2) The current efficiency is less than 100% because of side reactions.
(3) Active material is sometimes unavailable because of cell design.
(4) The stoichiometry of the cell reaction requires the use of water or some other non-energy-producing component.
(5) The storage containers for the materials and the auxiliary equipment represent an appreciable fraction of the total system weight and volume.
(6) The electrical resistances in the cell reduce the total available energy.

Types of Electrochemical Cells

For simplicity, electrochemical fuel cells and batteries can be divided into three main classifications, in which active materials having similar properties are grouped together. These three classifications, respectively designated primary cells, consumable-electrode fuel cells, and invariant fuel cells, are described separately in the following.

Primary Cells

Conventional primary cells differ from other electrochemical cells in that the active materials are self-contained and neither the active materials nor the electrolyte need be circulated for maximum performance. Typical primary-cell systems include a zinc anode with a cathode of manganese dioxide, silver oxide, mercuric oxide, or copper oxide, or a magnesium anode with a cathode of manganese dioxide, silver chloride, or cuprous chloride.

Because of their simplicity, primary cells are widely used as small portable sources of electric power. In general, the theoretical capacity of primary cells is considerably less than that of other systems because of the limitations placed on the active materials. These limitations are in part due to cell design, shelf life, and the cost of materials. The highest capacities of primary cells are approximately 80 watt-hr/lb and 7·5 watt-hr/cu in. The recently announced zinc-oxygen fuel cell is a variation of the air cell and has characteristics similar to those of both consumable-electrode and primary-cell types.

Consumable-Electrode Fuel Cells

Consumable-electrode fuel cells are electrochemical systems in which the reaction products cannot be removed without a change in the electrolyte composition. The anode materials in this class of fuel are metals with a high energy content (aluminium, magnesium, lithium, and sodium) typical systems including a magnesium anode with a chlorine cathode, or a sodium anode with an oxygen cathode. The reaction products are materials

which cannot be removed by simple processes. In the operation of some of these types of cells, the electrolyte may be circulated and the reaction products removed by filtration or complexing. In others, water may be added to maintain optimum electrolyte concentration.

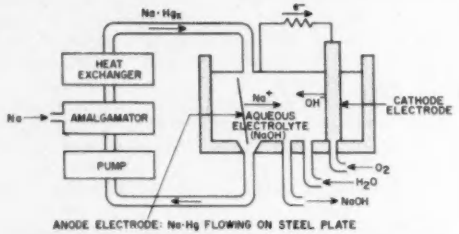

Fig. 3. Schematic arrangement of a sodium-amalgam consumable-electrode fuel cell.

Despite their advantages over conventional primary cells of higher theoretical energy content, the full value of most of these systems is realized only when water is readily available. On a volume basis and under certain conditions of hydrogen storage, consumable-electrode fuel cells will have a greater capacity than the hydrogen-oxygen fuel cell, described below. Consumable-electrode fuel cells will have limited application because of the limited availability and high cost of reactant materials. The only advantage of these cells is their power density, which makes them suitable for some specific military applications. The sodium-amalgam/oxygen system of the type shown in Fig. 3 is the most highly developed of the consumable-electrode cells.

Invariant Fuel Cells

In the invariant-type of cell, the reactant materials form a product which can be removed from the cell without change in the electrolyte. The operating conditions of the cell require that there be no side reactions, corrosion, or deterioration of the electrodes. The most desirable anode-cathode couples are those in which water, carbon dioxide, and nitrogen are the sole reaction products, because these materials can be removed easily from the cell. For this reason, typical systems utilize oxygen as the cathode, with hydrogen, hydrocarbons, alcohols, aldehydes, or hydrazine as the anode, as discussed below. The invariant fuel-cell systems are important because total available energy density approaches the theoretical maximum, and their long operating life with little maintenance provides economical long-term operation.

The electrochemical systems which meet the requirements of invariant operation fall in three broad classes, i.e., (1) hydrogen-oxygen systems, (2) direct and indirect cells using low-cost carbonaceous fuels, and (3) low-temperature cells using special reactant materials.

Hydrogen-Oxygen Fuel Cells:—

The hydrogen-oxygen fuel-cell system shown in Fig. 1 is the most highly developed of all the fuel-cell systems and operates at practical power levels and good efficiencies for long periods. The most widely used types of hydrogen-oxygen fuel cells include low-temperature, low-pressure cells, high-temperature, high-pressure cells, and ion-membrane cells. Of these, high-temperature, high-pressure fuel cells operate at high current densities and are the most compact of the three types. A typical cell of this type has an anode electrode of porous sintered nickel and a cathode electrode of porous sintered nickel pre-oxidized in lithium hydroxide, the electrolyte being an aqueous solution of potassium hydroxide. The operating pressure is 400 psi and the temperature from 200 to 240°C.

Because of this high-temperature operation, the life of the cell is limited by rapid deterioration of the cathode electrode, the longest operational life so far reported being about 1500 hr. Also because of the high temperature involved, the cell must be heated to start operation. When the cell is not operated at maximum power, some of the output may be used to maintain the cell temperature; a power output of 100 W is the minimum practical capacity that can maintain self-sufficient operating temperature. A further disadvantage is that these cells require hydrogen of high purity and oxygen which is free from carbon dioxide, because carbon dioxide forms a carbonate with an alkaline electrolyte. Although air can be used if the nitrogen and carbon dioxide are removed, the compression of nitrogen reduces the energy content of the system. High-temperature operation permits relatively easy removal of the water produced.

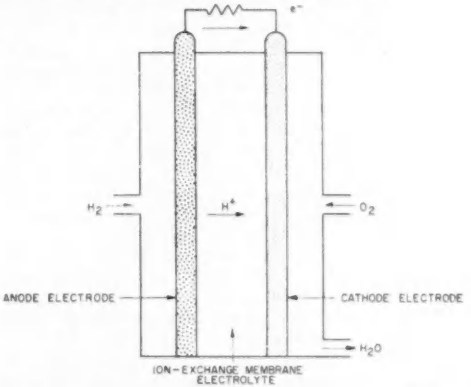

Fig. 4. Schematic arrangement of an ion-exchange membrane fuel cell.

Of the low-temperature, low-pressure cells, which also use an aqueous solution of potassium hydroxide as the electrolyte, one type, designed for operation at 85°C and atmospheric pressure, has an anode electrode of Raney nickel and a cathode of porous nickel or silver with a silver catalyst. Another type, operating at 70°C and atmospheric pressure, has both anode and cathode electrodes of porous carbon with a catalyst. As distinct from high-temperature cells, this type of cell does not require the use of extremely pure reactants, as the carbon electrodes are relatively insensitive to the catalytic poisons produced. The major factor affecting the operational life of this cell is the "wettability" of the porous carbon electrodes.

Low-temperature, low-pressure cells are simple, need little maintenance, and are easy to operate. In addition, they have a reasonable initial cost, and a long operating life (up to two years). Cells having anode materials such as carbon monoxide, alcohols, and aldehydes have been operated with good results at low temperatures. For long-term operation, however, the carbonate formed must be removed because the electrolyte is alkaline. The vaporized water product is passed into the hydrogen and oxygen feed gases and is removed by circulating the feed gases in a condenser. The cell is

designed so that this process occurs mainly in the hydrogen feed. The water is condensed in a separate unit and the feed gases are recirculated. For low-power applications, a considerable dilution of the electrolyte can be tolerated; because a 1-A cell produces less than 1 lb of water during 1000 hr of operation, recirculation is not necessary.

The ion-exchange membrane cell, which operates at ambient temperature and pressure, has both anode and cathode electrodes of platinized nickel gauze, the electrolyte being an ion-permeable membrane, made of phenol sulphonic acid formaldehyde resin, which permits hydrogen ions to migrate from the anode electrode to the cathode electrode during current flow. In this cell (Fig. 4), hydrogen ions react with oxygen and the electrons at the cathode electrode to form water. Although the water is automatically rejected, so that no special equipment is needed, the humidity on the electrodes must be controlled to prevent drying. Another important feature of the ion-exchange membrane is the use of an acidic electrolyte, which prevents carbonization of the electrolyte and permits operation of the cell in air. The life of such a cell is more than one year.

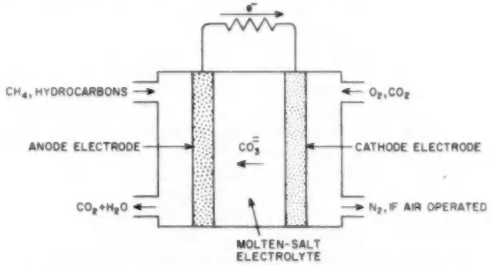

Fig. 5. Schematic arrangement of a molten-salt fuel cell.

As an example of the comparative performance of these three types of cells on a basis of their weight, it may be said that a high-temperature, high-pressure cell has a maximum power output of 50 W/lb and a thermal efficiency of up to 80%, as compared with 20 W/lb and 65 to 70% for a low-temperature, low-pressure cell, and 12 W/lb and 65 to 70% for an ion-exchange membrane cell. In this connection, it should, however, be appreciated that high-capacity primary cells, such as the zinc-silver oxide primary cell, offer definite advantages over invariant fuel cells for low power requirements and short-term operation.

Various other methods of supplying hydrogen for large- and medium-power cells have been described, the most attractive methods being those which produce hydrogen by the dehydrogenation of methanol or similar materials, or which convert hydrocarbons, in the presence of steam and various catalysts, to hydrogen and carbon dioxide. The carbon dioxide is then removed by the Gerbotol process.

Fuel cells of the hydrogen-oxygen system may eventually compete with conventional heat engines, because the starting materials are both economical and easy to handle. Hydrogen-oxygen systems which are most tolerant of impurities in the hydrogen and are capable of operation in air at atmospheric pressure could most readily use hydrogen produced in this manner.

Invariant Fuel Cells using Low-Cost Carbonaceous Fuels:—

The most promising invariant fuel cell is one which uses a low-cost carbonaceous material for the anode and which, on reaction with oxygen, produces carbon dioxide and water in stoichiometric amounts. The use of carbonaceous materials in fuel cells such as the molten-salt fuel cell shown in Fig. 5 has been hindered by the fact that hydrocarbons, which are not electrochemically active at low temperatures, require a molten-salt electrolyte. Although the molten-salt electrolyte presents several serious design problems and makes small units impractical, these high-temperature cells should find wide application in large power stations because of their high thermal efficiency.

The following generalizations may be made concerning the material limitations and electrode reactions in these fuel-cell systems:—

(1) A carbonate electrolyte is required to maintain invariant-cell conditions.
(2) Free-energy efficiences up to 78% and thermal efficiencies up to 60% have been reported for various carbonaceous fuels in the temperature range from 550 to 700°C.
(3) Operational life is short, owing to loss of electrolyte by the vaporization and corrosion of construction materials. The best reported operating life has been six months.
(4) There is a potential problem of carbon deposition because of the Boudouard equilibrium, i.e., $2CO \rightarrow C + CO_2$. This reaction can be controlled by a proper choice of electrode materials and incoming-gas temperature.

The objective is to produce a fuel cell which can use these materials at temperatures below 100°C and at atmospheric pressure. The problems arising from the handling and storage of hydrocarbon anode materials would be considerably fewer than those encountered with hydrogen. If the initial cost and size can be reduced, the invariant carbonaceous cell would be suitable as a power source for a wide variety of applications which now use conventional heat engines.

Some progress has been made towards this goal. One fuel cell has been demonstrated which operates on propane under ambient conditions. Another has been reported to give good performance with a fuel gas consisting of propane mixed with 33% hydrogen.

The redox fuel cell shown in Fig. 6 offers another approach to the utilization of coal and cheap hydrocarbon anode materials at near-ambient conditions, and avoids the problems encountered in the handling of fused salts. The basic problems of redox systems include a lack of reduction-oxidation couples

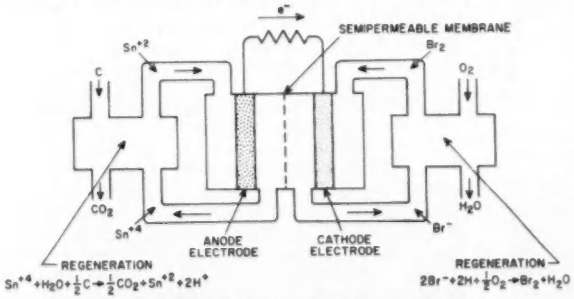

Fig. 6. Schematic arrangement of a redox fuel cell.

providing favourable cell voltages and the difficulty in handling bromine. The membrane separating the anode and cathode materials must have a high electrical conductivity but must be impermeable to the active ions.

Low-Temperature Fuel Cells:—

Some anode materials which can be used in ambient-temperature invariant fuel cells are the partially oxygenated organic materials such as methanol, formaldehyde, formate ions, and hydrazine. Present ambient-temperature fuel cells which employ these organic materials use alkaline electrolytes and produce carbonates as the reaction product. Because hydrazine is reduced to water and nitrogen in alkaline electrolytes, it can be coupled to an oxygen cathode to form an invariant system. For special applications, the handling properties of hydrazine may make it a more desirable anode material than hydrogen. The operating characteristics of this system are not at present known.

Regenerative Fuel Cells for Space Applications

Three primary sources of energy may supply the electric power to a space vehicle, i.e., chemical, nuclear, and solar. Chemical energy is limited as a primary power source in space applications because of its low energy-to-weight capacity. Until the reliability problems associated with a nuclear-energy source for space applications are overcome, solar energy is the only practical source of power. However, devices which use solar energy require a secondary power source for dark-time operation.

The high efficiency and simplicity of electrochemical processes have led to their consideration for space applications as a part of closed-cycle systems in which the chemical energy is continuously regenerated by solar or nuclear energy. These electrochemical systems are important for the following reasons:—

(1) They can be used as secondary power sources.
(2) They can be used as energy converters with special properties.
(3) They can provide, in one system, a combined high-efficiency energy converter and energy-storage device.

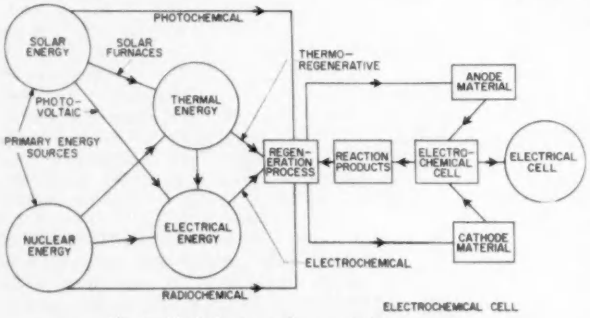

Fig. 7. Block diagram of regeneration processes.

The block diagram in Fig. 7 shows the overall processes of regeneration. Two primary sources of energy have been considered, nuclear and solar energy.

It is a basic requirement that the reactions in the regenerative electrochemical cell be reversible, i.e., the anode and cathode materials must react electrochemically to form a product which must dissociate, without side reactions, to reform the reactants; otherwise, the system would have a very limited cycle or operating life. Other important performance considerations of the electrochemical system include energy density per unit weight and volume, overall efficiency, and power output per unit weight and volume.

Four methods of regenerating the chemical energy in a regenerative fuel cell by dissociation of the reactant materials are (1) photochemical, (2) radiochemical, (3) thermochemical, and (4) electro-chemical. Because the direct processes for generating chemical energy photochemically and radiochemically are inefficient and offer many experimental difficulties, various indirect methods are being considered. Some of these methods, which involve the conversion of solar or nuclear energy to an intermediate form of energy (thermal or electric), are shown schematically in Fig. 7. For space applications in the present and the immediate future, these indirect processes seem the most practical on the basis of efficiency and design reliability. At present, energy-storage systems using electrochemical regeneration (the common secondary or storage battery) are the only systems in use. In particular, the nickel-cadmium secondary battery is used, although its capacity is as low as 1 watt-hr/lb under certain operating conditions. Other secondary systems either cannot be hermetically sealed in present designs or do not have the cycle life of the nickel-cadmium system. A possible exception is the cadmium-silver oxide battery.

The disadvantages of conventional secondary batteries have increased the need for new electrochemical regenerative couples, but the requirement of reversibility greatly limits the available reactant materials, particularly anode materials. For example, the hydrocarbons, alcohols, formaldehyde, boron hydrides, and hydrazine cannot be electrochemically regenerated under reversible conditions. Although the hydrogen-oxygen couple shows the most promise for the development of an electrochemically regenerative secondary cell, the energy efficiency of the cell will probably never exceed 50% because of the large difference between the voltage required to electrolyse water at a practical rate and the operating voltage of the cell. The practical use of hydrogen-oxygen cells will also be determined by the handling and storage problems of the reactant materials and the problems of separating liquid and gases in zero-gravity fields.

A zinc-oxygen reversible system is also being considered. Feasibility studies on new secondary couples utilizing alkali-metal or alkaline-earth-metal anode materials and various high-capacity cathode materials are in progress. However, the irreversibility of these anode materials in aqueous electrolytes requires the use of a non-aqueous electrolyte.

Thermal regenerative systems are attractive because they have a relatively high conversion efficiency, require a minimum of mechanical devices in high-temperature environments, and can be used in space applications where heat rejection from a thermal cycle is a problem. Lithium hydride and closely related ionic-hydrides systems, using, for example, lithium as the anode and hydrogen as the cathode in the electrochemical cell, are the only practical systems proposed to date. Although it is known that the efficiency of practical thermal regenerative systems will be lower than

that of conventional heat engines, further investigations will determine their ultimate practicability.

All the direct photochemical regeneration processes under investigation have low efficiency ratings. Most of the endothermic photochemical reactions reported are irreversible and are physically unsuitable. The NOCl system, using nitric oxide as the anode and chlorine as the cathode in the electrochemical cell, is the best so far reported, and has a theoretical efficiency of 70%. The efficiency of a silicon photovoltaic converter is approximately 12%. Photochemical systems based on the decomposition of water in the presence of cerous ions have an efficiency of approximately 0·1%.

The radiochemical regenerative fuel cells are also characterized by a low efficiency. Efficiencies of 3 to 5% have been obtained on systems using gamma rays from a cobalt-60 source to decompose acidified ferrous sulphate

(*Concluded on page 119*)

The Fatigue Strength of Vehicle-Engine Crankshafts

By E. GASSNER and W. SCHÜTZ

From *Motortechnische Zeitschrift* (*MTZ*), Germany, Vol. 22, No. 8, August 1961, pp. 321–323, 3 illustrations.

IN contrast to many other components of vehicles, the crankshafts of diesel or petrol engines must be able to sustain the highest stresses occurring under working conditions with complete safety, no matter how frequently the peak stresses may occur. These stresses are generally due to the firing pressure, which gives rise to alternating bending moments. If the inertia forces are smaller than the gas forces, as is usually the case, the inertia forces will not increase the amplitudes of the dynamic stresses, but will have a favourable effect on the mean stress, the highest inertia forces occurring at maximum running speed. In four-stroke engines, the highest firing pressures are probably obtained under optimum mixture conditions, i.e., at reduced speeds.

The stresses due to torsional vibration are generally less important than the bending stresses caused by firing loads in modern designs of crankshafts for engines with up to six cylinders, in view of the considerable amount of overlap provided between the crankpins and journals. It is a fact that most service failures of vehicle-engine crankshafts are pure bending fractures. Torsional crankshaft failures are exceptional nowadays, though they may occur, for instance, when the crankshaft has large masses at both ends (a flywheel at one end, and a dynamic starter unit at the other), so that torsional resonances may appear within the running range.

The assessment of crankshaft suitability as regards fatigue strength should therefore be based primarily on the maximum firing pressure. A first difficulty arises in this connection if the engine under consideration is still in the design stage or if no indicator diagrams have been obtained. In such cases, the firing pressure is estimated from previous experience. Diesel engines have peak pressures up to about 1400 psi without pressure-charging, and up to 2000 psi with exhaust-gas turbo-charging. For petrol engines, the normal peak pressures at full load are between 575 psi (throttled engines) and 850 psi (highly rated engines). With petrol engines, however, "pinking" can raise the pressure by as much as 30%; in diesel engines, unusual operating conditions causing pronounced diesel knock can cause a similar rise in firing pressure.

If the firing pressure is known or can be estimated reliably, the value of the bending moment can be determined for the most vulnerable cross-section of the crankshaft. In most cases, this cross-section is situated in the web, between the journal and the crankpin, and much more rarely in the crankpin itself. Whether, for this assessment, use should be made of the highest firing pressures occurring in normal running or the peak pressures obtained under exceptional operating conditions, such as knocking, is an open question but, in order to estimate on the safe side, and in view of the unpleasant consequences of a crankshaft fracture, it is advisable to add 20% or 30% to the normal firing pressure at full load for such calculations.

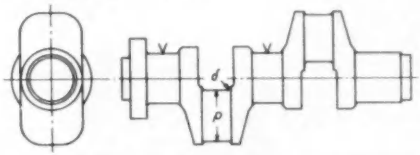

Fig. 1. Simply supported beam arrangement assumed for crankshaft calculations.

The crankshaft stress is assessed on the assumption that the crank-throw is simply supported in two bearings, as shown in Fig. 1, and that the other main bearings have no effect. It has been established by strain-gauge tests on running engines at the Motor Industry Research Association in England[1], and at the Fatigue Strength Laboratory, Darmstadt, that this calculation errs on the side of safety and is also valid for crankshafts with bearings between each cylinder. The calculation, however, does not take into account the effect of the bearing supports in the crankcase, which varies according to their stiffnesses. A more accurate determination can be made by static tests on the crankshaft in its crankcase. In these strain-gauge tests, the gas forces are simulated by hydraulic pressure exerted on the piston. For these tests, however, the firing pressure again must be known or estimated reliably, so that the best and most accurate (and also the most costly) method is strain-gauging of the crankshaft in the running engine. This method eliminates uncertainties as regards firing pressures and allows the stresses due to various engine operating conditions to be investigated.

Methods of Increasing Fatigue Strength

In new designs of crankshafts, the cylinder centre distances and the required bearing lengths usually have fixed values, so that the web thickness is predetermined. Nevertheless, with highly loaded crankshafts it is advisable to try to see whether improved stress conditions are possible by increasing the web thickness at the cost of a reduction in bearing length, or by increasing the fillet

radius between the crankpin and web. This latter method particularly can bring about a fairly substantial improvement with only minor alterations[2]. Wherever possible, it is advisable to use a ratio of fillet radius to crankpin diameter ρ/d (Fig. 1) of about 1 : 10. Every effort should be made to avoid fillet radii of less than 0·08 in., as the manufacture and checking of such small fillets under production conditions entail considerable difficulties.

An increase in the journal and crankpin diameters (and hence in overlap) also has a beneficial effect. So, too, does an increase in web width, provided that this is permissible as regards crankshaft balancing. Tests at the Darmstadt Laboratory have shown that the permissible bending moment increases approximately in proportion to web width; consequently, without reaching unduly large dimensions, a widening of the web will result in a considerable increase in fatigue strength, as shown in Fig. 2.

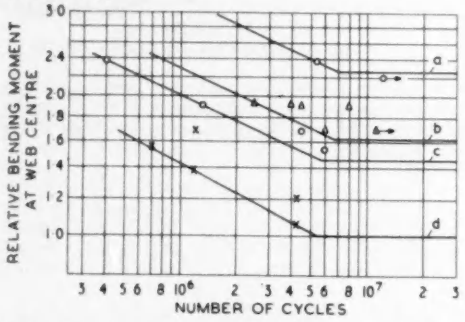

Fig. 2. Relative bending moment at web centre as a function of load cycles (a) for a crankshaft with a rolled fillet and wider web, (b) for a crankshaft with a rolled fillet, (c) for a salt-bath-nitrided crankshaft, and (d) for a standard crankshaft.

If the shape of the crankshaft can no longer be modified, and the fatigue strength must be improved because of service failures or increased working loads, then the first inclination frequently is to employ a higher-grade material with a higher static rupture strength. It has been found, however, that in this respect the crankshaft is one of the least favourable components of vehicle construction, since it hardly shows any response to increases in ultimate tensile strength above the usual value of about 54 tsi. Far greater prospects of success are offered by methods producing favourable compressive surface stresses in the more vulnerable sections, such as rolling, peening, or shot-blasting of the radiused fillets, and salt-bath nitriding [3,4] of the entire crankshaft. All these methods have been and are being used in mass production, despite some disadvantages. Fig. 2 gives a comparison of the gains in fatigue strength obtainable by rolling and by salt-bath nitriding, and shows that increases of about 45% by salt-bath nitriding, and about 60% by rolling, have been obtained for the permissible bending moment of the type of passenger-vehicle crankshaft considered in these examples. Fillet-rolling in conjunction with an increase in web width has produced an increase in fatigue strength by a factor of about 2·2. Obviously, increases of this magnitude cannot be expected to be obtained in all cases. However, with crankshafts, a reliable gain of the order of only 20% in fatigue strength is a very considerable improvement, and should be sufficient in most cases to avoid further recurrences of fractures in service.

Two further methods, which are more rarely used, are gas nitriding of the entire shaft (this is generally not considered suitable because of its cost, although it is used in a British racing-car engine), and an increase in the induction-hardened area of the crankpin up into the web itself. As hardening of the bearing surface of the crankpin is necessary in any case, this method could provide quite a considerable gain in fatigue strength without high additional costs, though its adoption in mass production raises considerable difficulties and has been confined to a few large vehicle manufacturers. However, now that medium-frequency equipment is available for such applications, it may be assumed that induction hardening of the fillet transition from the crankpin to the web will be used more often in future. Although crankshafts treated in this manner have not yet been fatigue-tested at the Darmstadt Laboratory, it seems reasonable to expect an improvement of the same magnitude as with fillet-rolling.

If only the bearing surface of the crankpin is hardened, a distance of at least 0·08 in. should be maintained between the end of the hardened zone and the radiused fillet; moreover, the prescribed hardness-distribution pattern should be maintained accurately, to avoid any reduction in dynamic fatigue strength due to hardness variations in the fillet.

All the methods used to produce favourable pre-stressed conditions in the crankshaft have the disadvantage of a possibility of crankshaft distortion as a result of the treatment. Some of the gain in fatigue strength may then be offset by the cost of the straightening operation subsequently necessary. Moreover, it is known that straightened crankshafts tend to distort again after a short period of service in the engine. With a salt-bath-nitrided crankshaft, it is claimed to be possible to avoid distortion by a fairly tedious preliminary thermal treatment, so that full benefit can be derived from the increased fatigue strength. Another advantage of salt-bath nitriding is that it allows a heat-treatable carbon steel to be employed, instead of an alloy steel, without any fears that, as a result, a smaller gain in fatigue strength will be obtained.

Cast Crankshafts

With regard to the configuration of a crankshaft for optimum stresses, e.g., by means of stress-relieving recesses, the possibilities of forged crankshafts are very limited if costs are to be kept to an acceptable level. Cast crankshafts allow much greater freedom in this respect[5,6,7] and in recent years the use of cast crankshafts, particularly of spheroidal-graphite iron, has shown a continuous increase. It is likely, however, that this is mainly decided by economical considerations, since, despite its optimum configuration, a crankshaft of spheroidal-graphite iron cannot possibly attain the load-carrying capacity of a forged crankshaft with the same fillet radii and web thicknesses. The potentialities of spheroidal-graphite cast iron can be exploited in new designs only if full attention is given to the particular properties of this material at the earliest design stage of the engine, or if the forged crankshaft previously considered had a narrow web. The substitution of a spheroidal cast-iron crankshaft for a forged crankshaft can, of course, be considered if the forged crankshaft has not been fully stressed up to its fatigue limit, so that it is, in fact, an oversize design as regards fatigue strength. Forged crankshafts and cast

crankshafts should not be compared on a permissible stress basis, as is often done, but rather on the basis of the permissible bending moments. The maximum nominal stresses of cast crankshafts can obviously be raised to higher levels by suitable design of the web and the crankpin. However, a favourable design of the web, incorporating, for instance, stress-relieving recesses or hollow-cast crankpins, is associated in most cases with an appreciable reduction in sectional modulus. Thus, the result is that, despite the higher permissible stresses, the permissible bending moment will be lower.

An example of the use of a spheroidal-graphite cast-iron crankshaft instead of a forged shaft is illustrated in Fig. 3. This cast crankshaft was required to have the same maximum permissible bending moment as the forged shaft (Fig. 3a) previously used, and no modifications whatever were to be made to the crankcase. As shown in Fig. 3b, the first attempt with the spheroidal-iron crankshaft gave, however, a less favourable result, despite a 50% increase in web width. The Fatigue Strength Laboratory therefore proposed a modification of the web shape, as shown in Fig. 3c, and also an increase in the fillet radius from 0·10 to 0·14 in. This improvement increased the sectional modulus of the vulnerable cross-section through the web, without any appreciable increase in weight, and enabled a 40% increase in the permissible bending moment to be obtained. It was also found that the weakest position of the improved design was no longer in the web but in the crankpin. As shown in Fig. 3, the load capacity of the forged crankshaft was even exceeded, although this was possible only because the forged shaft had a narrow web. An improvement of similar magnitude was also obtained with another cast crankshaft shaft of spheroidal-graphite iron.

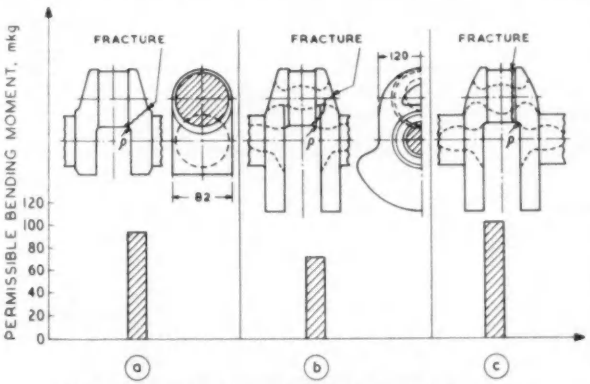

Fig. 3. Comparison of max bending moments between (a) a forged 0·45% carbon-steel crankshaft with a fillet radius ρ of 0·1 in., (b) a spheroidal-graphite cast-iron crankshaft (ρ = 0·1 in.), and (c) a spheroidal-graphite cast-iron crankshaft (ρ = 0·14 in.)

Composite (Built-up) Crankshafts

The build-up crankshafts considered under this heading are not of the Hirth type with peripheral serrations on the end-faces of the journal sections (these shafts have a load-carrying capacity reaching approximately that of crankshafts of the same dimensions forged from one piece), but are of the type in which the crankpins and journals, usually case-hardened, are press-fitted into the webs. This construction is fairly frequently used in petrol and diesel engines of from one to three cylinders, either in order to avoid the use of split connecting-rods or because it enables the highest loading capacities of all types of crankshaft to be attained. Case-hardening of the crankpin, together with the relatively low stress raiser in the press fit, gives a load-carrying capacity which is from two to three times greater than that of a forged one-piece shaft with the same pin diameters and web widths. This has been confirmed in a large number of tests on built-up crankshafts of various dimensions.

Comparative Assessments

In comparing results based on operating experience and on fatigue tests of crankshafts by various investigators, the following points should be borne in mind:—

(1) In view of the amount of scatter normally occurring in fatigue tests, assessments should be based either on large numbers of tests suitable for statistical analysis, or on an adequately large margin of safety below the fatigue limit, if based on a few tests, in order to avoid failures under operating loads occurring in service.

(2) The assessment of the dynamic loads acting on crankshafts requires reliable data on firing pressures under various operating conditions.

A question which to a large extent still remains to be clarified is that of the "trainability" of a material, which could be of considerable importance for crankshafts and fatigue testing. The most frequent stresses to which a crankshaft is subjected in service are below its fatigue limit, and it may be that the continuous variations from low stress levels to high stresses are conducive to an increase in fatigue strength. To verify this would require, however, a fundamental investigation into various crankshaft materials on a statistical basis. Some American investigations into steel test-bars seem to show that it is not impossible that this phenomenon, known as the "training effect", may be a misinterpretation of the normal amount of scatter inherent in fatigue tests. From experience at the Darmstadt Laboratory, however, there are indications that cast crankshafts (or at least those made of spheroidal-graphite iron) are apt to attain increased strength through "training" at initially lower load levels. If these indications materialized, a procedure would be available to provide a substantial margin of safety against service failures for cast crankshafts made of spheroidal-graphite iron.

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Calculation of the Heat Cycle of Steam Power Stations by means of Digital Computers

By H. HOTES

From *AEG Progress*, Germany,
No. 1, 1961,
pp. 75-80, 6 illustrations.

AT the beginning of 1957, the first AEG Computing Centre was established, its main function being the programming and carrying out of technical computations for all the factories and departments of the company. The procedure employed for the computation of heat cycles depends on the layout of the plant, and the plant diagrams of power stations are almost all different, even if only in detail. For setting up a computing programme, it is therefore necessary to feed the plant diagram in coded form into the computer before beginning the actual computation. Based on these data, the programme must then select the correct method of computation. How this task can be solved, even by computers with a small storage capacity, is described in this paper.

As a preliminary step, it is convenient to consider how the calculations for a single element of the feed-heating system, i.e., a feed heater, can be carried out by a computer. The most important task in the computation of a feed heater (Fig. 1) is the determination of the flow of bled steam. For this purpose, the equation for the heat balance of the equipment is set up and solved for the unknown flow m_1 in terms of

$$m_1 = \frac{M(J_2 - J_1) - \Sigma m_v(i_v - i_2)}{i_1 - i_2} \quad .. \quad (1)$$

To be able to use this equation, all enthalpies at the feed heater must be known. The outlet enthalpies of the drains i_2 and of the feedwater J_2 result from the technical data of the heater. If p is the extraction pressure, i_2 is found as the saturation enthalpy corresponding to p, so that

$$i_2 = i'(p) \quad .. \quad .. \quad .. \quad .. \quad .. \quad (2)$$

If the heat-transfer characteristics of the heater are represented by the temperature difference Δt, the outlet temperature T_2 of the feedwater is then

$$T_2 = t_s(p) - \Delta t \quad .. \quad .. \quad .. \quad .. \quad (3)$$

where $t_s(p)$ is the saturation temperature corresponding to the pressure p. If P is the water pressure, the enthalpy

$$J_2 = J(P,T_2) \quad .. \quad .. \quad .. \quad .. \quad .. \quad (4)$$

In manual calculations, $i'(p)$, $t_s(p)$, and $J(P,T_2)$ are taken from steam tables, which are so extensive that it is impossible to store them in a computer. In machine calculations, the numerical tables must therefore be replaced by equations of state[1], which are, of course, nothing more than computing instructions for calculating function values from one or two given variables. Such calculations can, however, be carried out very simply by a machine. Methods of setting up equations of state have been fully described elsewhere[2] and will not be further discussed here. A system of equations of state which reproduce the values in the VDI Steam Tables[3] and which are suitable for electronic computers has been given by the author[2]. These equations form the basis of the AEG Steam Tables[4]. The other enthalpies i_1, J_1, and i_v, as well as the flows M and m_v required in eq. (1) are not determined by the data of the heater, but depend on the parts of the plant from which the pipes come.

To enable the machine to find the correct values, each pipe in the diagram is given a number. A pipe is understood to mean a connection between two points in the plant, along which the thermal state of the steam or water flowing through it does not change, except for unavoidable but small changes due to radiation and pressure losses. Associated with each pipe number are one or more cells in the memory store of the computer, in which the values of flow and enthalpy of the substance flowing in the pipe are retained.

The simplest way of allocating the pipe numbers to the addresses of the store locations is to provide a consecutive series of cells, starting, say, with the address A. The numbers 0, 1, . . . N may be used for the pipes. The store location associated with the pipe numbered n is then $A + n$. The maximum number of pipes required is 60. For the computation of a heater, in addition to the technical data, such as pressures and temperature rise, the numbers of the pipe connected to the heater must also be prepared as input data, the corresponding numbers of these pipes being shown encircled in Fig. 1.

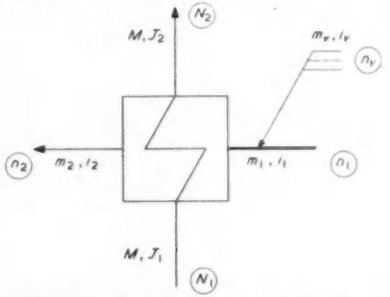

Fig. 1. Schematic representation of a surface-type feed heater.

Before beginning the actual calculation of the flow of bled steam according to eq. (1), all the necessary data are "read" from the pipe-number store, this transfer being best effected with the aid of a sub-programme. The number of the pipe, e.g., n_v, is transmitted to the sub-programme. It then "writes" the flow m_v and the enthalpy i_v into definite stores, e.g., in the register of the arithmetic unit. When all flows and enthalpies have been derived, the bled-steam flow m_1 is computed according to eq. (1); from the flow balance

$$m_2 = m_1 + \Sigma m_v \quad .. \quad .. \quad .. \quad .. \quad (5)$$

the flow m_2 of the drains is obtained. Both flows are required for computations relating to other parts of the power station. Finally, therefore, the pairs of values (m_1, i_1) and (m_2, i_2) must be written into the stores of the associated pipes, n_1 and n_2, this also being effected by means of a sub-programme.

All the elements of a feed-heating system, e.g., pumps, drain coolers, and de-aerators, can be treated in an exactly similar manner to that described for the above heater. All the computations have, in fact, the following features in common:—

(1) The main calculation consists of solving the equation for the heat balance of the element for one unknown, which may be a flow, an enthalpy, or an enthalpy difference. Examples of the three cases are feed heaters, mixing operations, and drain coolers.
(2) Some of the flows and enthalpies associated with the element are determined by its technical data.
(3) The other flows and enthalpies required for the heat balance depend on what parts of the plant are connected to the element by pipes.

Because of these common characteristics the following computing procedure can be adopted for all elements:—

(1) Computing the enthalpies from the technical data.
(2) Reading all further flows and enthalpies from the pipe stores.
(3) Computing the unknowns from the heat balance.
(4) Writing the calculated data into the pipe store.

The computation is thus basically the same for all types of elements of the feed-heating plant, the only differences being in the formulae used in (1) and (3) above.

Computation of the Complete Feed-Heating System

Now that it has been shown how the computation for each individual element of the feed-heating plant can be carried out, the next step is to consider how the separate calculations must be combined so that finally all the flows and enthalpies of the feed-heating train are known.

For electronic computation, the two main questions to be taken into account are related to how the machine can distinguish between the different types of elements in the feed-heating train, and in what sequence should the computations for the individual elements be carried out. The distinction between the different types of elements is important because, as already stated, the separate calculations for each type are carried out according to somewhat different formulae and thus according to another programme.

To distinguish between the different types of elements in the feed-heating train, each type which might possibly appear in any arrangement is given a type number. These numbers are allocated once and for all (unlike the pipe numbers, which may be different for every form of connection). As a definition of the term "type", it can be said that two elements are of exactly the same type if they are computed according to the same formulae. A maximum of 15 different types is required.

For each type a sub-programme is set up, with which the computations appropriate to the type can be carried out. The first instruction of each of these sub-programmes is written into a special store, which can easily be derived from the type number. It is simplest if, as in the case of the pipe numbers, a series of consecutive storage cells is selected as starting points of the type programmes, beginning with the address B. If, then, the computation for an element of type T is to be carried out, the main programme computes the starting point $B + T$ of the type sub-programme, inserts this value as an address into a "jump" instruction, and carries out the instruction. In this way, it is ensured that the correct computing procedure is employed for each type.

With regard to the question of the sequence of the computations for the individual elements, the optimum sequence depends on the connections of the power-station plant and cannot well be formulated as definite rules. It is evident, however, that the machine may also be made to compute in a different sequence. This may involve more computation than is essential, but, in view of the high speed of operation of electronic computers, this is of no great importance.

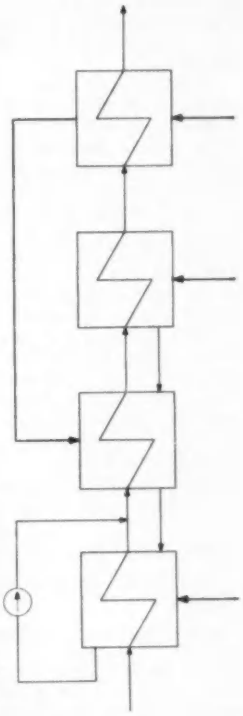

Fig. 2. Schematic arrangement of part of a feed-heating plant.

As a first step, the input data of the plant elements are written into the machine, actually in the sequence in which they are physically connected, starting with the condenser. After the data of one element have been written in, the associated enthalpies are computed, and then all the data required for further computation are retained in the store. The next element is then written in. With this procedure, the condition of the feedwater on the inlet side of an element is known when the other enthalpies are determined. It is thus possible to determine in advance the performance of, for example, feed heaters connected to drain coolers or pumps.

It is now unnecessary to allocate special pipe numbers to the separate parts of the main feedwater pipeline between each two elements of the feed-heating plant (pipes N_1 and N_2 in Fig. 1), because the connection of the elements is determined simultaneously by the sequence of the data input. When all the elements have been written in in this manner the heat-balance equation is evaluated, i.e., for feed heaters the bled-steam flows are computed. The order is now reversed, beginning at the boiler and ending at the condenser. This sequence is more advantageous because the drains from heaters generally flow into the heater arranged one step back and therefore have to be known when the heater data are computed.

Two cases in which this sequence of calculation gives incorrect results at first are illustrated in Fig. 2. The top element (I), with which the calculation starts, is a desuperheater. As the bled steam which flows through (I) is determined by the heater (III), the enthalpy increase is not calculated correctly. In the bottom feedheater (IV), the drains are pumped into the feedwater pipeline, thus

increasing the enthalpy at this point. When computing (III), the magnitude of the enthalpy increase is not yet known, so that in this case an incorrect bled-steam flow is calculated.

To correct such errors, the whole computation is repeated, naturally making use of the results already obtained. A check is then made as to whether the results of the two computations agree. If this is not the case, one or more further computations must be made until finally no change in the results occurs.

In the example in Fig. 2, a different bled-steam flow (III) is determined in the second computation. This changes the drains flow to (IV) and consequently the bled-steam flow (IV), which again changes the enthalpy of the mixture before the heater (IV). On the third computation, a different flow (III) is therefore found, but now the change is so small that there is practically no change in the enthalpy after (IV), so that, on the fourth computation, the same results, are obtained as on the third. The enthalpy increase in the desuperheater (I) is determined by the flow (III) and is therefore also finally determined on the fourth computation. The design of the feed-heating system can therefore be computed in a simple manner for any connection without the necessity for any special preparation of the input data.

Computation of Turbine Power

The turbine power P can be calculated from the equation

$$P = \eta_i \, (\Sigma M_v \, \Delta i_v - P_{\text{mech}}) \quad . . \quad . . \quad . . \quad (6)$$

where Δi_v represents the enthalpy difference between two points on the expansion curve of the turbine, M_v the steam flow in this part of the turbine, P_{mech} the mechanical losses, and η_i the generator efficiency. The enthalpy values on the expansion curve and hence also the differences Δi_v are starting points for the heat cycle computation, as also are P_{mech} and η_i. The flows, on the other hand, are initially unknown and are derived from the computation of the feed-heating plant.

The computed bled-steam flows are stored in the pipe-number stores. To represent the course of expansions it is therefore sufficient to state the enthalpy and pipe number at each extraction point. Making use of the pipe number, the bled-steam flow can be read from the pipe-number stores, enabling the steam flow through the following turbine stages to be calculated.

For practical computation, it is advantageous to write the values of the expansion curve into the computer first. The enthalpies i_v, with the corresponding pipe numbers $\pm n_v$, are fed in in sequence from the boiler to the condenser, and the pairs of values $\pm(n_v, i_v)$ are stored in consecutive cells. The sign $\pm$ indicates whether the turbine steam is fed in (+) or extracted (−). An infeed of steam occurs, for example, at the low-pressure gland, which is supplied with gland-sealing steam. Further, the enthalpies i_v and, where known, the flows m_v are fed to the pipe-number stores associated with M_v. This is necessary in order that these values may be available for the later computation of the bled-steam flows by the sub-programmes for the elements of the feed-heating system. The gland-steam flows are, for example, known before the computation is commenced.

A block diagram for power computation is shown in Fig. 3, in which v in block (1) is used as the index of the cyclical programme. The initial values for the flow M_v and the enthalpy i_v are the boiler data M_k and i_k in block

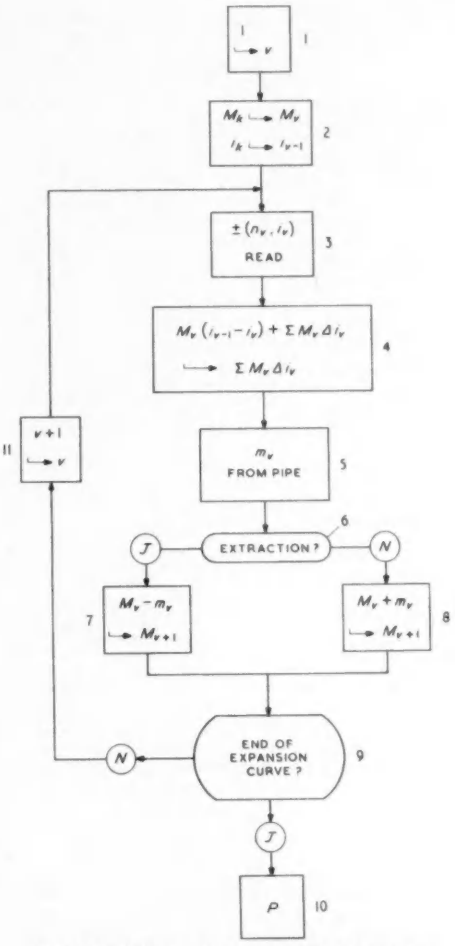

Fig. 3. Block diagram for computing turbine power.

(2). As the first step of the actual computation, the following point of the expansion curve is read from the store (3), and the power which the turbine delivers up to this point is computed in block (4). The flow from pipe n is then read from store (5), and from this the steam flow in the following turbine stages is computed in blocks (6) to (8). If i_v is the end-point of the expansion curve (9), the power output of the plant (10) is given by (6); otherwise, the index v is taken as $(v + 1)$, as in block (11), and the next section of the turbine is computed.

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Automatic Control in Glass Manufacture

By P. M. CUPIDO

From *Philips Technical Review*, The Netherlands,
Vol. 22, No. 9/10, 1960/61,
pp. 311-319, 8 illustrations.

THE mechanical production of large quantities of glass imposes demands on the manufacturing process that cannot be met by pot-melting—the oldest method of glass melting and still in use for glasses of special quality or for making relatively small quantities. A process which is better adapted to this purpose is that in which melting is carried out in a tank furnace, the charge and the molten glass being in direct contact with the walls and floor of the furnace. The floor, together with the part of the walls, forms the melting tank (or "end"), and is an oblong trough built up from blocks of refractory material. The batch is fed in at one end (the "dog-house"), and the molten glass is withdrawn at the other. At the melting end, the charge is subjected to the necessary time-temperature programme, which consists of creating an appropriate temperature gradient along the trough and carefully controlling the rate at which the glass traverses this gradient. Unlike pot-melting, which is a discontinuous process, this is a continuous process.

It would be ideal if all the glass issuing from the melting tank could be subjected to exactly identical conditions. This is not the case, however. Owing to the complex currents arising, and to unavoidable "blind spots", the duration of flow through the melting tank differs for the glass in different regions of the tank. Good glass can be obtained only if no part of the mass is heated for too short a time, i.e., the duration of flow must be above a certain minimum. A long duration of flow is equally undesirable, however, for economic reasons and also for reasons of quality because, if the glass stays for a lengthy period in the melting tank, the composition of the molten mass changes, owing to the disparate evaporation of certain constituents and to the solution of wall material. As a result, the duration of flow must lie within critical limits.

An unchanging flow pattern in the melting tank is therefore of particular importance, and the conditions governing this pattern must be kept carefully constant. These conditions are the method of feeding-in the batch mixture, the withdrawal of the molten glass, and, above all, the heat transfer in the melting tank and the temperature at various places above and below the glass surface.

In a tank furnace, two preheating systems are available, i.e., a recuperative or a regenerative system. In the recuperative system, which is generally used only for relatively small furnaces, the air to be heated and the combustion gases flow through separate channels (the recuperator) divided by ceramic or metal partitions, through which heat is continuously transferred. For larger furnaces, the regenerative system is more economical. The furnace is flanked on both sides by a box-like brick structure (Fig. 1), with a refractory lining and containing an open-stacked structure of fire-bricks ("checkers"). This structure (the regenerator) has a high heat capacity and offers little resistance to the alternating flow of the hot combustion gases and the air for preheating. The burners (3a) and (3b) operate alternately. Thus, with the reversal dampers (6a) and (6b) in the position shown in Fig. 1, the burners (3b) are in operation and the burners (3a) are extinguished, the combustion air being preheated in the regenerator (5b) and the combustion gases delivering heat to the regenerator (5a). After every 20 to 30 min, the situation is reversed.

In the recuperative system the burners work continuously, there is no reversal, and a temperature equilibrium is established in the heat exchanger; as a result, constant processing conditions are easy to achieve. By contrast, in the regenerative system the temperature of the heated air is continually changing, and each reversal severely disturbs the conditions prevailing in the furnace. Despite this drawback (which can be reduced by shortening the reversal periods), the regenerative system is preferred for quantity production because, as already mentioned, it is more economical. The reason is the better heat transfer in the regenerative heat exchanger, in which the air is preheated to a temperature of 1000 or 1100 °C, i.e., 300 to 400 °C higher than in a recuperator.

After leaving the melting tank, the glass enters the working tank (or "end"), likewise a refractory structure but of smaller dimensions. In automatic production, the main function of the working tank is to let the glass settle to a lower temperature. The glass flowing out of the melting tank has a temperature of 1400 or 1500 °C, which must be reduced to 1000 or 1100 °C for working. Part of this reduction, which must be uniform and thus calls for suitable time and space, is effected in the working tank.

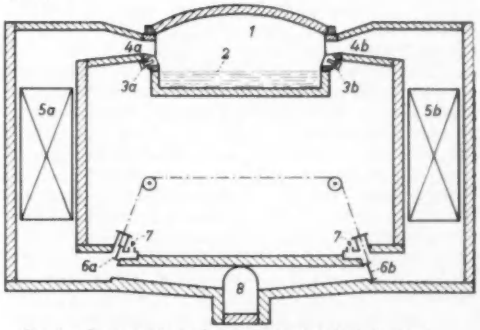


Fig. 1. Cross-section of a regenerative tank furnace. (1) Tank furnace. (2) Glass level. (3a), (3b) Oil burners. (4a), (4b) Burner ports. (5a), (5b) Regenerators. (6a), (6b) Reversal dampers. (7) Combustion-air feed. (8) Chimney flue.

From the working tank the glass flows into one or more feeders. These are long channels of refractory material, in which a proper combination of cooling and heating gives the glass a constant and uniform temperature. The feeders terminate at the glass-working machines. Depending on the product to be made, the glass is fed to the machines continuously or discontinuously. A machine which turns out glass tubing or rods receives a continuous supply, whereas a bulb-blowing machine is fed with successive portions termed "gobs", which are cut off with special shears.

Parameters amenable to Automatic Control

Bearing in mind the production process involved in a regenerative tank furnace, consideration will now be given to how it is possible to effect automatic control of the processing conditions, i.e., of furnace temperature, of automatic reversal, of the gas pressure in the furnace, and of glass temperature and level in the feeders.

Furnace Temperature

As already mentioned, a constant heat transfer from the furnace atmosphere to the glass is of great importance, and it is therefore essential to keep the temperature in the furnace and its distribution as constant as possible. In the case of an oil burner, it is easy to control the temperature by mounting a suitable sensing element, e.g., a thermocouple, near to the flame and transmitting the resulting signal to a valve-operated control device for regulating the rate of oil supply. However, for various reasons, a simple system of this type is unsatisfactory. Similarly, although some improvement can be obtained by mounting the thermocouple in a locality where it is least directly influenced by the flame, e.g., in the crown of the furnace, this method has the disadvantage that the thermocouple is now more or less part of the crown, which has a very high heat capacity. As a result, changes in flame temperature will be measured with a considerable lag, making rapid and stable automatic control impossible.

The right answer to this problem is to provide every condition governing the properties of the flame with its own control circuit. The first thing to do is to insert a thermostat in the oil line to keep the fuel temperature constant, and a pressure regulator in the atomizing system. The next step is to keep the oil flow rate constant. For this purpose, a constriction is included in the line (orifice plate or venturi), and the pressure drop across it acts, via a regulator, on a control valve in the oil line. This system quickly corrects disturbances without any risk of instability. A fall in oil pressure—due, for example, to partial clogging of a filter—can be corrected in a matter of a few seconds.

Also of importance are the flow rate of combustion-air and its temperature. The flow rate directly determines whether the flame is surrounded by an oxidizing or a reducing atmosphere, and also influences the length and radiation of the flame. It is therefore desirable to measure and regulate the flow of the combustion air. However, the construction of most furnaces does not make this possible. The resistance which the burner ports and the regenerator offer to the air flow causes the air to be distributed over the ports in a way that can hardly be controlled. Attempts to control the air distribution by means of dampers in the burner ports have been made, but all have come up against severe practical difficulties.

A system that is both feasible and highly effective relies on a separate regenerator for each burner port. The air required by each burner is fed in at the bottom of the corresponding regenerator. The air feed can be controlled by a system similar to that used for the oil feed, the air flow being measured with an orifice plate or venturi tube and kept constant by means of a regulator and control valve. The oil and air regulators are coupled via a ratio controller, which maintains the desired ratio of oil to air when one or the other is being varied.

The temperature of the combustion air remains an intractable problem. This temperature is highest immediately after the burners have been reversed, and then gradually falls. The temperature drop can be reduced by shortening the period between successive reversals, but the period must not be too short, since every reversal severely disturbs the prevailing conditions. All flames are extinguished during this operation, and the composition of the furnace atmosphere alters radically. The most favourable compromise is usually to fix the period between 20 and 30 min. To minimize the disturbance, the reversal itself must be made to take place as rapidly as possible.

Automatic Reversal

The reversal of the system is obviously an operation that should be done automatically, the more so since a furnace with separate regenerators in any case involves various operations which must be carried out in rapid succession.

Suppose that the burners on the left are in operation. When the moment for reversal arrives, the first operation is to shut off the oil feed to the left-hand side, and the second to lower the pressure of the atomizing air. The next operation is to supply combustion air via the regenerator chamber on the right, its first function being to dispel the combustion gases still present in the chamber. Not until this has been properly done may the atomizing air for the right-hand burners be raised to the requisite pressure and the oil feed turned on. If the latter were done too soon, lack of oxygen would prevent immediate combustion of the atomized oil, resulting in a badly smoking flame and possibly after-burning in the regenerator.

To make these simple operations take place automatically it is necessary to introduce a number of reliable safety measures. Defects in the reversing mechanism, for example, must never give rise to a situation where oil continues to flow to the burners, but no combustion or atomizing air. The consequence could obviously be a serious explosion.

A safeguard reversing system has been developed for the automatic furnaces in the Philips glass factories and incorporates control of the dampers and of the supply of oil to the burners and atomizing air. The initial reversing command is given by a clockwork control timer, and each successive command cannot be issued until the preceding command has been properly executed. The system is so designed that the oil feed is shut off automatically in the event of a fault or a failure, e.g., of the mains voltage or of the compressed air.

Gas Pressure in the Furnace

A parameter whose constancy has an important bearing on the process is the gas pressure inside the furnace. The combustion process gives rise in the furnace to a certain pressure distribution, and the gases present acquire certain velocities. By measuring and controlling the pressure at a suitable point, it is possible to stabilize the distribution pattern as a whole. The pressure in the furnace must be somewhat higher than outside; otherwise, cold air would be sucked in through various apertures and would adversely affect the temperature distribution and perhaps also the combustion. The difference in pressure should only be slight, however, since the escape of hot gases entails a loss of heat and moreover accelerates furnace wear.

In manually-regulated tank furnaces, the positive pressure is adjusted with stack dampers, which are generally broad and heavy cast-steel plates in the flue to the chimney stack, the control range being covered by moving the damper up or down a few centimetres. For automatic control, such a damper is scarcely suitable as its large mass (often increased by counter-weights) does not lend itself to rapid control, and the available maximum displacement of only a few centimetres precludes the precision and stability required. It would be an improvement to mount a narrower and much

lighter damper on the existing damper; the reduced width then gives a greater stroke, and the smaller mass allows faster and more accurate control.

An effective and inexpensive method of automatic control depends on the use of an adjustable "artificial draught", as shown in Fig. 2. In the flue (1), through which the combustion gases enter the chimney (2), is a circular aperture fitted with a short side-pipe (5) containing a butterfly-valve (6). This valve is operated by a pneumatic or servo-motor (7) and can function much more quickly than is possible with the stack damper in the systems previously discussed. The butterfly-valve controls the pressure prevailing in front of the damper (3), which is adjustable by means of a hand winch (4), by admitting a greater or smaller quantity of air.

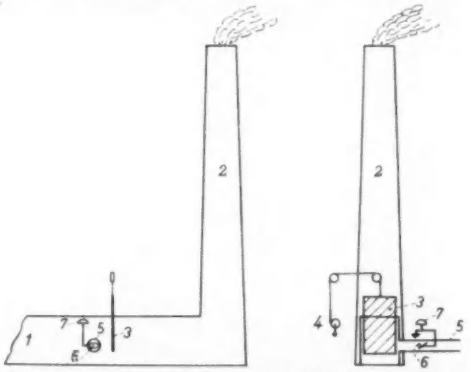


Fig. 2. Automatic control of pressure inside a furnace by means of an artificial draught.

Even with this system, however, the control action is not fast enough to deal with the consequences of gusts of wind at the mouth of the chimney. Gusts of wind give rise to often steep-fronted pressure waves which travel at the speed of sound into the furnace itself, where they upset the prevailing conditions. In this respect, a high brick stack is inferior to a short, possibly metal, chimney, in which an appreciable negative pressure can be created with the aid of an air-injector, thereby minimizing the effect of pressure variations caused by strong gusts. The correct pressure in the furnace is obtained by suitably adjusting the flow resistance in the flue by means of a damper.

The system using a short chimney, however, is not without its drawbacks. Thus, the short chimney does not conform with the regulation in many countries that large quantities of combustion gases containing a high percentage of sulphur (as in the case of fuel oil) must be discharged into the atmosphere above a certain height. Furthermore, the energy required for injection pushes up the running costs to a multiple of those incurred with a high stack.

Glass Temperature and Level in the Feeders

The feeders are required to deliver per unit of time a constant quantity of glass of constant viscosity. Since there is no practical means of directly measuring and regulating viscosity, an indirect means of controlling it is adopted, i.e., by controlling the temperature of the glass. However, the viscosity is not solely dependent on the temperature, but also on the composition of the glass. Changes in composition sometimes occur in the form of irregularly distributed inhomogeneities (cords), which may be due to non-uniformities in the batch composition. The less such deviations occur, the better is the temperature control system able to maintain the desired viscosity.

The quantity of glass which the feeder delivers per unit time depends on the viscosity and level at the effluent end, and it is therefore necessary to keep the level of the glass constant. Consequently, this level is continuously measured, and deviations from the desired height are fed back to act on the rate at which the batch mixture enters the furnace. Controlling the automatic batch feed in this way also helps to keep the melting conditions constant, as well as the flow pattern in the tank furnace. Furthermore, experience has shown that accurate level control prolongs the life of the melting tank appreciably.

Performance Criteria for Control Systems

A principal requirement to be met by control equipment is that, if the value of the controlled quantity changes, the correct value should be rapidly restored. A limit is set to the speed of the control action by the properties of the controlled process and of the control instruments used. If this speed is exceeded, the system becomes unstable, i.e., after a disturbance the value of the controlled quantity continues to oscillate at a certain amplitude around the desired value.

The operation of a control system is based on comparing the measured value of the controlled quantity with the desired value. Two main categories can be distinguished, i.e., discontinuous and continuous control. The first category (e.g., simple two-step or on-off control) has the advantage of considerable simplicity and reliability. A process controlled by a discontinuous controller, however, is by nature unstable, the controlled value oscillating continually around the desired value.

In cases where the amplitude of the oscillation is excessive, continuous control is indicated. The controller may have proportional or integral action, whereby the position of the final control element is proportional to the deviation ε from the desired value, or to $\int \varepsilon dt$ respectively. Purely proportional action has the disadvantage that the desired value is never entirely reached, whereas this is not the case with integral action. The best result is obtained as a rule by combining proportional and integral action. A derivative action, proportional to $d\varepsilon/dt$, may be added. This has a damping function and is only employed to improve the stability of control systems where particularly fast corrective action is required.

Sufficient stability can almost invariably be ensured by not raising the sensitivity of the control equipment too far. There are cases, however, where the response of the system would be too slow, because of the transfer lag or dead time of the process itself, of the measuring unit or of the final control element.

A property which all automatic control equipment must possess, especially for continuous processes, is a high degree of reliability. This is a matter of both plant design and choice of control equipment. In the plant, it is necessary to ensure that any component which is at all vulnerable is readily accessible and can be quickly replaced, and the same applies to control valves, orifice plates, etc. incorporated in the pipelines. It should be possible to isolate all these components from the rest of the equipment, and they should be provided with individual by-pass lines which can be shut off to allow

(*Concluded on page 90*)

A Computer-Controlled Automatic Production Line for Deposited-Carbon Resistors

A PRODUCTION line which is stated to represent an entirely new concept in the automatic manufacture of electronic components by combining statistical quality control with fully mechanized processing, all under the guidance of a digital computer, has been installed in the North Carolina works of the Western Electric Company. In addition to controlling step-by-step details of manufacture, the computer can accept a production schedule for a full month's output and can thereafter automatically issue detailed instructions to the fabrications machines to make and package in the quantities and resistance values desired any or all of four basic power sizes of deposited-carbon resistors of the type shown in Fig. 1.

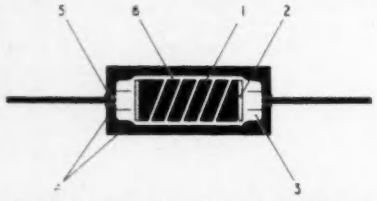


Fig. 1. Detail of the type of deposited-carbon resistor produced. (1) Film of carbon with helical groove. (2) Gold-sputtered terminations. (3) Gold-flashed cap. (4) Epoxy encapsulation and seal. (5) Percussion-welded lead. (6) Protective air space.

In addition to the computer and control cabinets, there are eleven machine stations in the line, three of these stations being used only for testing. The length of line, the layout of which is illustrated in Fig. 2, is 110 ft, with a maximum machine width of about 6 ft. Between the first four stations of the line, the resistor core is transported by blowing through a plastic tube under a gentle air pressure. In succeeding operations, the resistors move from machine to machine on individual stainless-steel pallets moving along continuously running conveyor belts, as shown in the detail (*R*) in Fig. 2, and under the control of special equipment (*F*) and (*P*).

The digital computer (*A*) has a 4096-word magnetic-drum memory and includes the input and output circuits required to control the programming, set-up, and feedback control of the individual machines. It also provides initial set-up of wattage size at eight machines and of resistance value at six machines. The computer output is stored in transistorized registers, such set-ups as wattage size, gas flow, and core speed requiring binary registers for each machine. Those machines requiring a decimal set-up, i.e., the helixing machine, the marking machine, and the two inspection storage bridges, share a single binary-coded decimal register. The input unit is an analogue-to-digital converter. Although it is time-shared between the individual input stations, the 140,000-bit/sec speed at which it sweeps data into the computer precludes any delay in the operation of the computer. Output and input are controlled by a station (*B*).

In the coating station (*C*), the tiny ceramic core, which is the nucleus of the resistor, passes through three separate chambers of a horizontal furnace at a speed regulated by a special control device. At the same time, a horizontal three-roller support system causes it to rotate to ensure uniformity of coating. To guard against oxygen contamination, nitrogen, continuously flushed through the deposition area of each chamber, forms a pressure seal against end-baffles. In the heating areas of each chamber, a temperature of over 2000°F is used to decompose methane, forming crystalline carbon on the core, which is then cooled to room temperature. Three parameters govern the resistance value of the coating, i.e., the speed of the core through the coating zone, the pyrolysis temperature, and the flow of methane. The computer controls these parameters through a feedback loop around the furnace, computing the control information from statistical quality-control data stored on the memory drum.

After cooling to room temperature, the core passes to the first inspection station (*D*), which forms a feedback loop from the coating furnace through the computer. In this station, the coated core passes between four probes, using the Kelvin-bridge principle. Analogue voltage, proportional to resistance, is digitized and is fed to the memory drum of the computer, where it is stored and sampled against the programmed requirements also

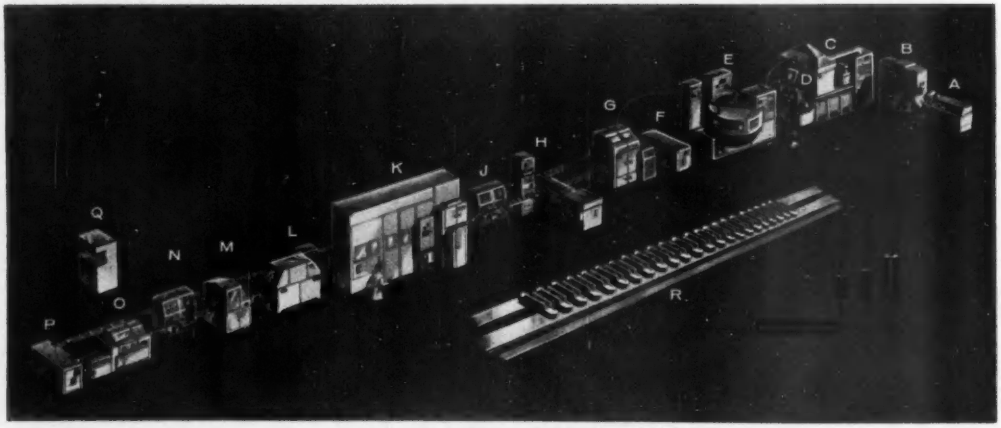


Fig. 2. Layout of the automatic production line.

stored on the drum. The results of this inspection form the basis for feedback control of the furnace, and a graph at this station records the test for visual monitoring. The inspection station also inserts magnetic slugs, as instructed by the computer, to separate individual lots of resistors when changes in resistance value or in resistor size are called for.

The carbon-coated core then passes to a terminating machine (*E*), which sputters a gold contact over each end. The core first goes to a pick-up station to be fitted with a mask for holding and protecting the centre of the core. Since there are four different sizes of resistor, as shown at the bottom right of the illustration, the computer programmes the correct mask sizes. The mask is then loaded onto a vacuum station and is covered with a bell-jar, which is pumped to a vacuum and is then back-filled at low pressure with argon gas, after which the ends of the core protruding from the mask are sputtered with particles from a gold cathode. Sputtering lasts for about 1 min, depositing a layer of gold of approximately 10 micro-inches in thickness, uniformity of deposition being ensured by means of two rollers, actuated by an external magnet, which rotate the core inside the mask for maximum exposure.

Fig. 3. View of part of the terminating station.

After leaving the terminating machine (Fig. 3), the resistors pass to a capping machine (*G*), where wire leads are attached to each end. The leads are first attached to tiny hexagonal caps of gold-plated brass by means of an automatic percussion-welding machine (*Q*) outside the line, the assemblies then being inserted into the capping machine, which feeds them into capping chucks. The capping chucks simultaneously press the assemblies over both ends, the capping force being sufficient to weld the gold plating of the cap to the gold on the ends of the core. It also creates a highly reliable, low-noise contact. The capping machine uses two different capping-assembly heads and three different sizes of caps, to cater for the four wattage sizes of resistor. The computer controls both switching of the assembly heads and changing the cap sizes. The automatic percussion-welding machine (*Q*) produces a weld at the joint of the solder-coated lead and gold-flashed brass cap by means of a high-intensity

Fig. 4. View of part of the second inspection station.

arc of extremely short duration (less than 300 micro-seconds). The machine, which has an output rate of about 3600 parts per hour, has changeable tooling to accommodate three different cap sizes and two wire sizes. Fail-safe devices shut off the machine or reject the part if no cap is fed, if a lead is not attached, or if a poor weld occurs.

In the helixing station (*H*), the resistor obtains a precise value, a helixing lathe cutting a helical groove along the carbon film on the core to obtain the desired resistance. Cutting is monitored by a computer-controlled bridge and is effected by rotating the properly chucked resistor against a diamond-impregnated wheel. During cutting, the bridge not only disengages the bridge lathe when the desired resistance is reached, but also senses any non-linearity indicative of chipping or thin spots in the coating, causing any such cores to be rejected automatically. The control circuits also reject any resistor which reaches its value before 75% of its length is used, or if it fails to reach its value in its full available length. Helixing is performed dry and continues until the final resistor value has been obtained, eliminating the hand-rubbing method of final adjustment previously used. The helixing-lathe bridge is slightly biased to compensate for machine inertia and for resistance changes caused by heat generated during grinding. These data are programmed and stored in the memory drum of the computer, which is also tied to a servo-mechanism for controlling the speed and pitch used for proper helixing. Helixing is accomplished in about 3 sec (a fraction of the time normally required), this being achieved by balancing the rotating mechanism and using a magnetic counterweight to hold the movable chuck assemblies against the diamond cutting wheel.

The feedback control and self-correction of the helix lathe bridge are based on a statistical quality-control analysis of values obtained at the second inspection station (*J*), where a Wheatstone-bridge, set by the computer to the desired nominal resistance value of each resistor lot, precisely measures the resistance of the resistor. Off-balance voltage is digitized and is fed back to the computer, which then computes the desired correction and adjusts the setting of the helixing machine.

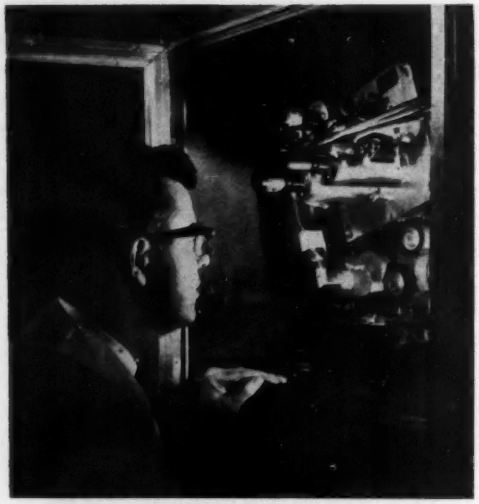


Fig. 5. View of part of the marking station.

Fig. 6. View of the packing station.

In this station (Fig. 4), defective resistors are automatically rejected, and visual monitoring is also provided.

After leaving the second inspection station, the resistor is fed into an encapsulating station (*K*), where a precured epoxy shell is fitted over the core and two partially cured epoxy pellets are inserted over each lead. Held between resilient-rubber chucks, the resistor moves through an oven for about 15 min at a curing temperature of over 300°F, the resilient chucks preventing trapped air from escaping and causing leaks in the finished resistor. The fully cured shell does not melt and rests on the gold caps of the resistor, retaining an air space along the resistor body to prevent organic contamination of the carbon film. The partially cured epoxy pellets on the leads soften, forming an effective seal with the shell. The resistors then pass through jets of cooling water to terminate curing of the pellets. Detection circuits in the encapsulating machine reject any resistors which have missing shells or pellets.

Following encapsulation, the resistor passes to a leak-detection station (*L*), where a holding-clip immerses it in a bath of hot water containing a wetting agent to prevent surface bubbles from clinging to the resistor body. The heat expands the air inside the capsule, and a series of ten photoelectric cells checks for air bubbles which would indicate a leak. A special device rejects improperly sealed resistors as they leave the tank, the heart of this device being a mechanical memory tab which is associated with each resistor holding-clip and which retains the identity of any individual resistor rejected at any one of the leak detectors. The machine is capable of detecting leaks as small as 2×10^{-6} cc/sec.

After leaving the leak-detection station, the resistor passes to a marking station (*M*), where a computer-controlled marking machine stamps the wattage, resistance value, production-lot number, and date on the encapsulated resistor. The machine (Fig. 5) uses a modified offset-printing technique, with the blanket roll and inking rolls mounted on a planetary-gear arrangement, permitting the type-head to remain stationary and also making it possible to add servo-drives for automatic type-changing. These drives, controlled by the computer, can set any one of 45 different code numbers with more than 1,500,000 permutations of code and resistance-value combinations. The automatic controls also provide blanket-roll cleaning between code changes and during idle periods, eliminating the possibility of the ink impressions drying on the blanket roll.

The resistor then moves to the third and final inspection station (*N*). This station is a feedback control point which resets the preceding inspection station to compensate for shifts in resistance values caused by the heat of encapsulation. Finally, the resistor moves to a packing station (*O*), where it is pushed into a bank between two loading jaws. When the bank fills, an anvil pushes the pre-positioned resistors into a block of styrofoam, which passes down a hopper into a loading magazine. This machine (Fig. 6) is also controlled by the computer, which actuates servo-mechanisms to control the loading-platform and anvil-stroke settings for each of the four sizes of resistor.

Automatic Control in Glass Manufacture

(*Concluded from page 87*)

replacement without having to close down the plant. To facilitate fault-finding, readily accessible and well-planned points, where the necessary check measurements can be made, should be provided. It is desirable that defects should be automatically localized and signalled by pilot lamps. In the choice of control equipment, reliability is also the dominant factor, cost being a secondary consideration.

Finally, it should be mentioned that, although the control devices used in the manufacture of glass have hitherto been almost exclusively pneumatic, the use of electronic controllers has started to gain ground. The fact that these devices possess the high degree of reliability required for industrial processes is partly attributable to the transistor. Electronic systems are particularly suitable wherever fast automatic control is called for.

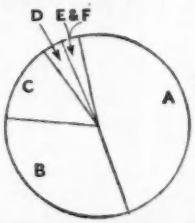
Factory Heating-1

The space heating of factories by electrical means can be achieved in a variety of ways which will be dealt with in the next Factory Heating Data Sheet.

Before deciding on any form of factory space heating—whether by means of electricity or not—it is as well to have clearly in mind all the components of the total annual running cost, and not merely the fuel cost, of the installation.

They are:

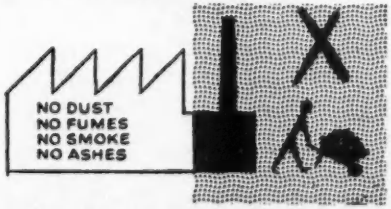
(A) The cost of the fuel or the electricity,
(B) Interest and depreciation on the capital cost of the installation,
(C) Labour,
(D) The cost of running auxiliary plant such as fans and pumps,
(E) Maintenance,
(F) Insurance.



In comparing fuel costs it should be borne in mind that electric heat is refined heat and has had all the fuss, bother and dirt of the conversion of fuel into heat taken out at the generating station.

In arriving at the true figures for capital cost and depreciation, maintenance and insurance, those connected with such items as boilerhouse, chimney, fuel store and access road should be included; labour costs should include such tasks as ash disposal. None of these items occurs when electricity is used, although space will be required for the electric boiler and storage vessels in the case of the type (h) following.

Electricity provides the ideal answer to the requirements of the Clean Air Act, the impact of which has introduced an important new factor during the last few years.



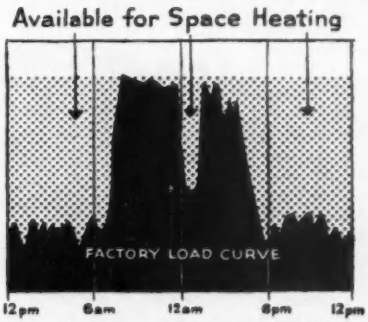
The following list gives the main types into which electric heating installations fall:

(a) High temperature ("infra-red") overhead heaters operating at near red heat.
(b) Medium temperature panels operating at surface temperatures of 400° to 600°F.
(c) Extended surface heating in the shape of floorwarming operating at temperatures up to 80°F.
(d) Oil and water filled radiators.
(e) Tubular heaters.
(f) Unit heaters.
(g) Storage block heaters.
(h) Electric boilers and water heaters operating in conjunction with hot water radiators or panels either with or without water storage.

All these methods of electric heating can be divided into two distinct classes:

(a) Those that utilise electricity during "off-peak" hours and store the heat so generated for use at a later period.
(b) Those that use electricity whenever the heating system is in use (i.e. direct electric heaters).

The use of a heat storage system in a small works on a block tariff takes advantage of the lower tariff offered for an off-peak supply, and in the larger factory on a Maximum Demand tariff means that the heating load



will not incur any M.D. charge. Alternatively there may be cases where the use of direct electric heaters can be integrated with other factory loads in such a way that they are not used during the factory peak periods and will thus incur no additional Maximum Demand charge.

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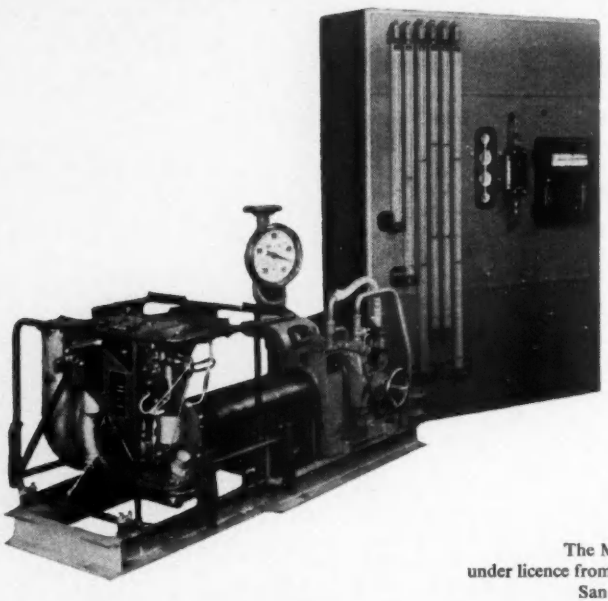

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7th EUROPEAN MACHINE TOOL EXHIBITION

Our issue for August 1961 included a preview of some of the equipment featured at the 7th European Machine Tool Exhibition, which was held in Brussels between September 3 and 12. In the following pages, details of a further selection of exhibits are given.

Wadkin Ltd.

Of the three machines exhibited by Wadkin Ltd., of Leicester, two of them served to demonstrate the outstanding progress made in high-speed machining techniques for non-ferrous metals. Thus, the Type L.H.R. Wadkin rotary miller is designed for the continuous milling of light-alloy components, and is being installed in the production lines of the motor industry and in other leading engineering firms where large-scale production on milling operations is required. Similarly, the Type L.C.6 Wadkin articulated-arm router is an inexpensive medium-capacity machine for the high-speed milling of light-alloy components. This machine will accommodate a large proportion of the work now being done on the company's Type L.C. heavy-duty machine and, since it is more versatile, the cost of many set-ups is reduced.

The third Wadkin exhibit was their Type T.C.D.1 positional drilling machine (Fig. 1), which has been specially designed for automatic operation from either punched tape or dial settings. The machine comprises an all-geared vertical drill-head unit mounted on a cross-rail which is, in turn, carried on twin columns, with power rise and fall to the cross-rail. Any number of positional changes can be carried out with an accuracy of $\pm 0{\cdot}001$ in. The table, measuring 42 × 66 in., has a longitudinal travel of 60 in. and is designed to support components weighing up to 5000 lb. The drill-head unit has a No. 5 Morse taper spindle and is suitable for drilling holes up to 2 in. in diameter in mild steel. Twelve spindle speeds, ranging from 60 to 1500 rpm, with six feeds from 0·004 to 0·030 in./rev., are available. A special drilling head can be supplied to incorporate tapping and drilling, giving five tapping feeds and seven drilling feeds.

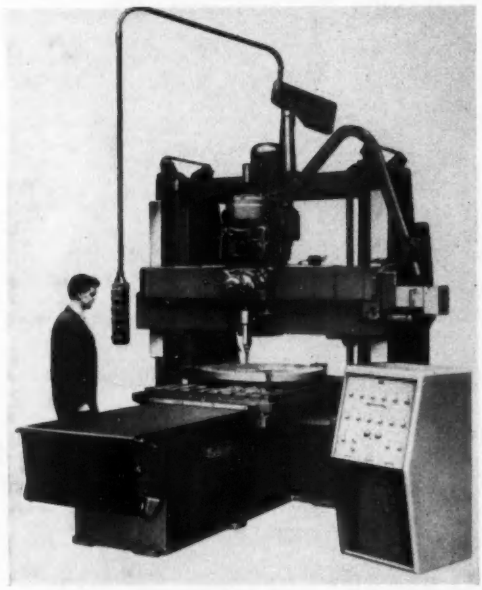

Fig. 1

As an alternative to the single-spindle, heavy-duty drill-head, a six-station turret can be offered, and this particular type of head was demonstrated on the Wadkin stand. The maximum drilling capacity in mild steel is $\frac{9}{16}$ in. diameter, and $\frac{3}{4}$ in. in cast iron, with a maximum tapping capacity of $\frac{1}{2}$ in. Whitworth. The drill-head has 6 in. of stroke for each of the turret positions, and provision is made for fast-approach drilling feed and fast retraction for each station. The speed range of the turret spindle is from 116 to 3000 rpm.

A. A. Jones & Shipman Ltd.

Quite apart from a wide range of their small tools and machine-shop equipment, including "Lamalock" surface plates, sine bench centres, the J. & S. air press, the J. & S.-Braunstone twist-drill grinder, and the Model 816 bench drill, A. A. Jones & Shipman Ltd., of Leicester, exhibited a representative selection of their grinding machines, including their Model 1540 "Super" surface grinder (developed from their well-known and established Model 540 grinder) and their Model 1212 high-precision cylindrical grinding machine, which has been introduced to fill the demand for a hand-operated machine for grinding small-batch work to limits of extreme accuracy in toolroom or production operations.

Also exhibited by the company was the J. & S.-Micromatic Model 761 vertical "Hydrohoner", which is made by Jones & Shipman under agreement with their associates, the Micromatic Hone Corporation of Detroit, Mich., U.S.A. This new machine (Fig. 2) has been specifically designed for microhoning to very close tolerances bores which are comparatively small in relation to their lengths. When using the full 15-in. stroke, bore diameters up to $1\frac{1}{4}$ in. can be microhoned. Larger diameters, but with shorter lengths, can also be accommodated. The spindle unit is housed in a hydraulically operated reciprocating quill. The spindle drive is from a 2-hp motor and provides an infinitely variable speed from 175 to 940 rpm, the reciprocating speed being infinitely variable up to 65 sfpm. A constant and positive rate of feed is applied by means of a "Micro-dial" unit, power for the feed cylinder being supplied by a separate hydraulic system. Initial tool expansion ensures that, at the start of the microhoning cycle, the honing stones are automatically expanded instantly to nominal bore size. Compensation for stone wear is automatic. The machine is stopped when the stones are completely worn down, as shown by a stone-life indicator. New stones must be fitted before the machine can be

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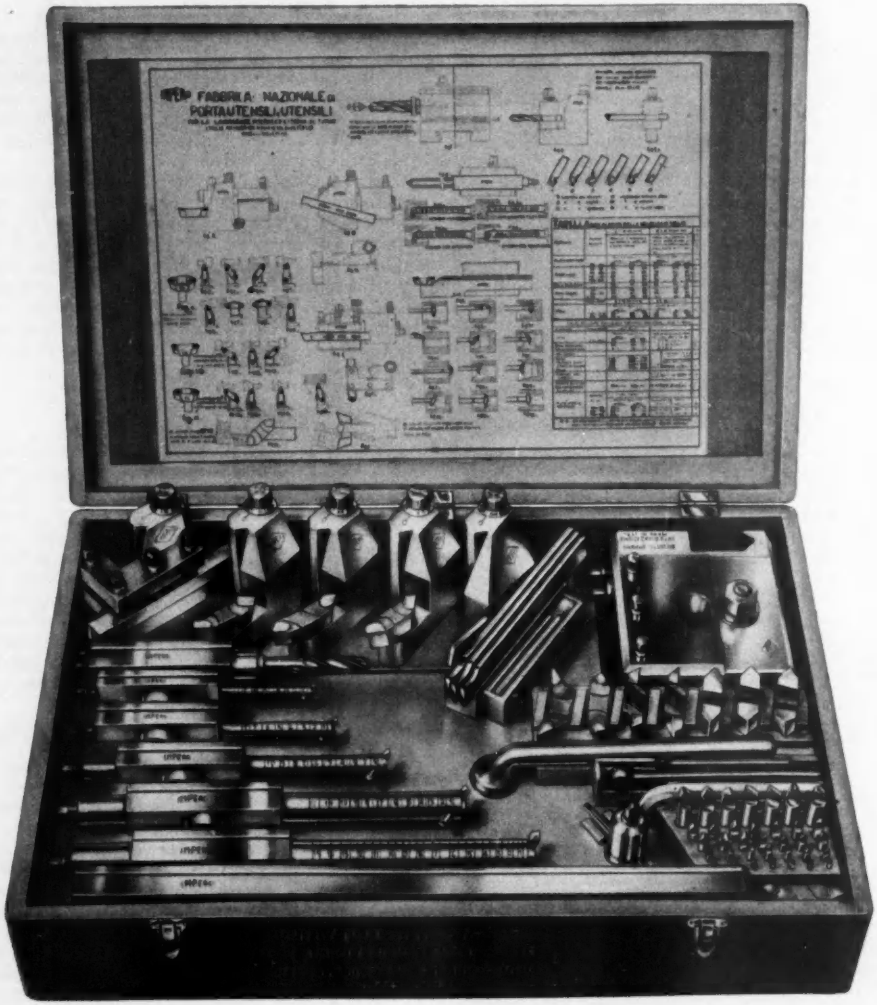

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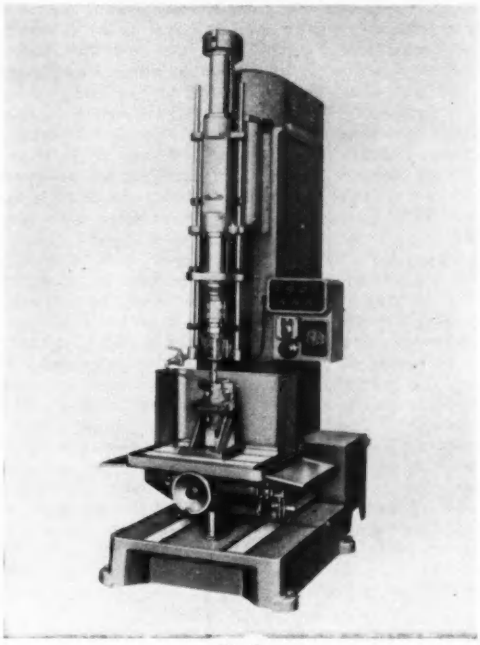

Fig. 2.

restarted. Automatic sizing is effected by a gauge-ring with its internal diameter of the required size. The ring is actuated by the tool to terminate the microhoning cycle when the bore reaches the gauge-ring size, repeat diametrical accuracies being of the order of 0·0003 in. or less. A coolant clarifier of the paper-roll type is supplied to ensure that the coolant is kept free from particles of swarf which might mar the surface finish.

Another interesting Jones & Shipman exhibit was their Model 310 cutter and tool grinder (Fig. 3) arranged for form-grinding by the incorporation of the new P.G. Series II "Projectorscope" and "Optidress" attachment. The "Projectorscope" is designed to use a tracing, instead of a graticule, for comparing the outlines of the wheel and workpiece, and simplifies the form-grinding of regular or irregular shapes by permitting visual control during all stages of grinding. A magnification of exactly ×25 is obtained by means of condensers and prisms, the silhouette of the workpiece being projected onto a screen of 7½-in. diameter for comparison with a tracing of 25 times the size of the form. This equipment is initially used for inspecting wheel forming when using the "Optidress" attachment and subsequently for visual control during actual grinding. The P.G. "Optidress" attachment is permanently mounted on the head of the machine and enables wheel-forming to be carried out under optical control without the use of templates. A built-in microscope facilitates centring and positioning of the diamond. A graticule in the microscope carries radii in steps of 0·010 in., from 0·025 to 0·375 in. The carrier unit is attached to a straight slide which gives a total movement of 1 in. and which can be set to any angle up to 180 deg.

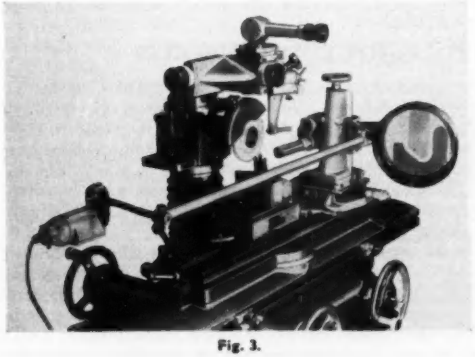

Fig. 3.

Landis Lund Ltd.

Exhibits by Landis Lund Ltd., of Keighley, Yorks., included the Gardner 2H30-30 double-spindle disc-grinding machine, one of a complete range of Gardner disc-grinding machines. This type of machine, which uses special Gardner "Wire-Lokt" abrasive discs, is capable of grinding two surfaces parallel in one operation on parts that have hitherto never been considered suitable for disc-grinding operations. In addition, parts can be ground to very close tolerances and to fine finishes. The capacity of the particular machine exhibited is up to 4 in. in width, using two discs of 30-in. diameter, each powered by a 30-hp motor.

Another exhibit from this company was the Landis Lund "Precimax" Type FB.2 double-ended precision fine-boring machine, which can be used in a wide range of fine-boring, fine-turning, facing, and other operations. This machine has a table area of 25 × 10 in., and table

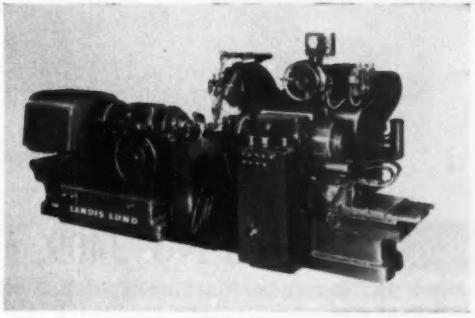

Fig. 4.

speeds are infinitely variable between ½ and 12 ipm. The machine exhibited was equipped for machining an automobile differential housing of malleable cast iron, this component being loaded in an air-operated single-station fixture and subjected to fine-boring, facing, and chamfering operations on identical bores at each side of the component. On each bridge of the machine was a Landis Lund heavy-duty fine-boring head, each equipped with facing slides, since the operation to be performed required the boring bars to pass through a hole of a smaller diameter than the one to be machined inside the component. The electro-hydraulic system on this machine provides for fully automatic operating cycles, twelve different sequences of automatic operation being available.

Other Landis Lund exhibits included, in addition to a 5″ Type DH automatic camshaft form-grinding

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machine, a 16″ Type DH automatic crankpin grinding machine. This latter machine (Fig. 4), which has a capacity of 16 in. swing by 32 or 42 in. length, has been American-designed specifically for the efficient grinding of crankshafts of all types on a rapid production basis, and was shown in operation grinding the crankshaft of a six-cylinder automobile engine. The machine, which is hydraulically operated, has a number of special features, including Landis Tool "Microsphere" bearings for the grinding-wheel spindle, telescoping slideway covers, automatic application of work-rests, and automatic sizing. The grinding-wheel feed is arranged for a quick approach of the wheel until it is in the cheek-grinding position. A reduced rate of feed is then engaged for grinding the cheeks, with further-reduced rates of feed when grinding the crankpin diameters, final sizing being effected by the Landis Tool "Microfeed", which operates in conjunction with automatic sizing by means of a pneumatic-electric contact-gauge. Dressing of the grinding wheel, which is 36 in. in diameter, is carried out by the recently introduced Landis Lund "Truform" wheel-dressing attachment. This attachment is mounted on the grinding headstock of the machine and, in addition to dressing the periphery of the wheel, also dresses the full 90-deg. radii on each corner. The crank-carrying fixtures are provided with hydraulic clamping, and longitudinal location for the crankshaft is both positive and accurate.

Kendall & Gent Ltd.

Exhibits from Kendall & Gent Ltd., of Manchester 18, a member of Associated British Machine Tool Makers Ltd., included their plano-milling machine and their Model FCG.30 automatic grinding machine for face-milling cutters. The plano-milling machine (Fig. 5) has a capacity of 6 × 6 × 20 ft and is equipped with three milling heads, one on the cross-slide and one on each of the vertical columns.

All three heads are self-contained units, each driven by a 30-hp motor mounted directly on the head. Flexibility in operation is obtained by permitting each individual milling head to run at the speed most suitable for its own particular type and size of cutter, irrespective of the speed of any other head. In addition, the individual motor drive permits a short and rigid transmission, ideally suited to the use of both carbide and high-speed steel cutters. Each spindle has sixteen spindle speeds, from 12 to 800 rpm. Selection of the required speed is by a lever control and handwheel, in conjunction with a direct-reading indicator dial. Spindles can be adjusted by power traverse or hand, a micro-adjustment being fitted to the hand motion for accurate setting. The vertical milling head spindle is also provided with infinitely variable boring feeds, with a range from ½ to 12 ipm.

All three milling heads and the table traverse are provided with electronically controlled infinitely variable feeds with a range of 1½ to 45 ipm. Change of feed rate is by a single control knob which can be operated whilst the machine is in operation; the feed rate in use is indicated on a large-diameter tachometer dial. Safety interlocks automatically reduce excessive traverse rates, thus preventing damage by careless use of the controls. Excessive depths of cut operate further safety cut-outs and virtually eliminate damage from such causes.

Spindle retraction and incremental feed allow the operator to control the locking, retraction, and resetting of the cutter spindles from a centralized control station. Operation of a rotary switch unlocks and retracts the spindle to permit the return of the component under the raised cutter; further rotation of the control switch returns the cutter and spindle to the precise position first set. The spindle then re-locks automatically, ready for the next cut. The incremental-feed system further extends the usefulness of the spindle-retraction feature by allowing a predetermined finishing cut depth to be automatically applied to the spindle position. Both systems are so arranged that all spindles can be operated simultaneously or independently, as required. When using the incremental-feed system, provision is also made to operate the table traverse and spindle resetting in a semi-automatic cycle, so as to accommodate workpieces requiring multiple cuts.

The machine is fitted with electronic "steering" equipment to provide facilities for steering the cutter by remote control round any shape of workpiece. This feature permits continuous metal removal on any component, irrespective of its contour, with a substantial reduction in machining time. Steering is effected by the operation of a small control knob mounted on a portable control station. The electronic control equipment is so arranged that the table and milling-head traverses are automatically and simultaneously determined, both in rate and direction, by the steering movements applied to the control handwheel.

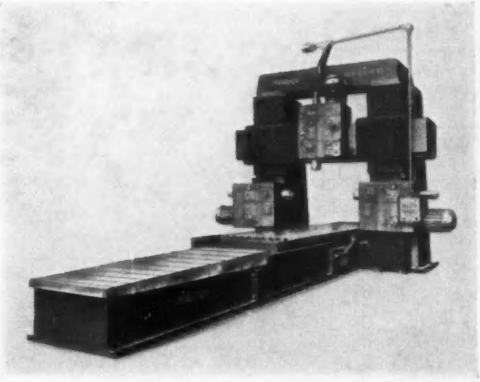

Fig. 5.

The new Model FCG.30 automatic grinding machine (Fig. 6) is designed for grinding the blades of inserted-blade face-milling cutters, either for the production of new tools or for regrinding existing tools after use. Both carbide and high-speed-steel cutters can be ground, as the machine incorporates an abrasive grinding wheel and a diamond wheel mounted on individual spindles, the diamond wheel being brought into use by swivelling the grinding-wheel unit through 180 deg. The main cutting edge of the cutters can be joined to the dish edge by one or more chamfers or by a radius. In the latter case, the whole contour of the blade, including the radius, can be ground in a single operation. The machine can also be used to carry out a cylindrical grinding operation to rough-grind the blades by a simple rotary movement—an important preliminary operation on newly rebladed cutters.

Automatic cycles for three different methods are incorporated in the machine and are selected from a control switch mounted on the operator's push-button

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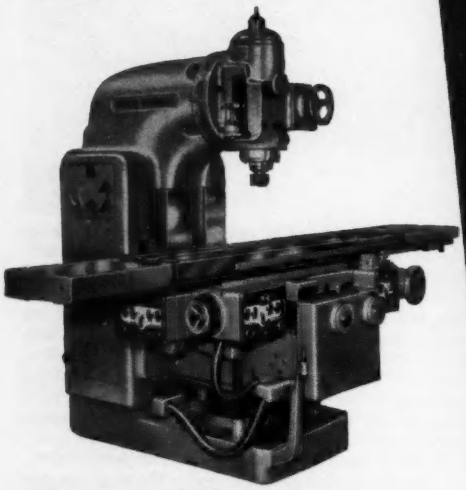

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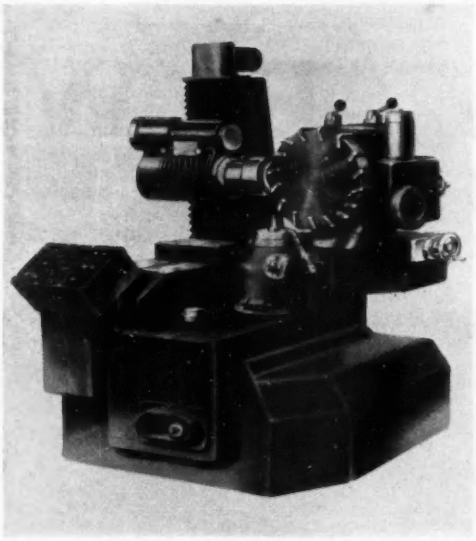

Fig. 6.

station. In each method the preset cycle of grinding repeats automatically until all blades in the cutter have been ground; after one full revolution of the cutter, the machine stops automatically. No dividing plates are necessary, since the blades themselves determine the required position by indexing against a flexible steel blade rest. The grinding spindle can be power-traversed in a vertical direction for height; in the horizontal plane, movement is either by hand traverse or by power in-feed increments, this latter movement serving to approach the grinding wheel towards the cutter.

Particular attention has been given to the design of the machine to provide simple and conveniently located controls. Also, to facilitate setting of the cutter radius, a setting gauge is available which operates on the comparator principle. Two dial gauges are employed, which are first set to zero from a setting piece of the required radius; the setting gauge can then be used to determine accurately the cutter position for producing the required radius.

James Neill & Co. (Sheffield) Ltd.

An extensive display of magnetic workholding, not only of equipment, but also of applications, was staged by James Neill and Co. (Sheffield) Ltd., of Sheffield 11, together with practical demonstrations of "Eclipse" hacksaw blades and other machine-shop tools.

"Eclipse" magnetic chucks in the widest possible range of sizes were shown, from the smallest rectangular models to the large high-power models for milling and planing applications. Circular models exhibited included a new addition to the range of sizes offered, i.e., a 15-in. model. In addition, demonstrations of the versatility of the "Eclipse" permanent electromagnetic chuck were given, as well as the use of many types of fixtures used in conjunction with a permanent-magnet chuck to provide a magnetic jig. A large number of such applications were illustrated, typical of many of which have actually been made to solve a number of particular problems.

Landis Machine-Maiden Ltd.

Among the range of equipment exhibited by Landis Machine-Maiden Ltd., of Hyde, Cheshire, particular interest attaches to their Type MB double-spindle threading machine. This machine (Fig. 7) has a maximum capacity of 1½ in. for bolts and pipes when fitted with "Lanco" Type R tangential die-heads. Alternative types of heads include the 1¼-in. Type T internal-trip tangential die-head used for pipe and nipple work and the 1½ Type S tangential die-head, which has a fully receding mechanism and can accommodate normal pipe sizes up to 2-in. bore. In addition, smaller sizes of head can be fitted to the machine, making it extremely versatile and capable of being economically equipped for a very wide range and variety of work. The die-heads are provided with an automatic trip mechanism which can be adjusted to provide varying thread lengths. The die-head can be closed either by the rearward movement of the saddle or by means of a conveniently located hand lever.

The headstock is a totally enclosed unit driven from a 5-hp motor through Vee-belts to an initial helical drive, from which power is provided to drive both spindles by means of pick-off gears, giving a choice of eight spindle speeds. Each spindle can run at a different speed, but both must run in the same direction. The carriage front is fully adjustable in both the vertical and horizontal directions, permitting the work to be precisely aligned with the cutting tool and the die-head and resulting in high-quality threads and exceptionally long tool life. A hammer-blow handwheel effectively increases gripping power and reduces operator fatigue. The manual

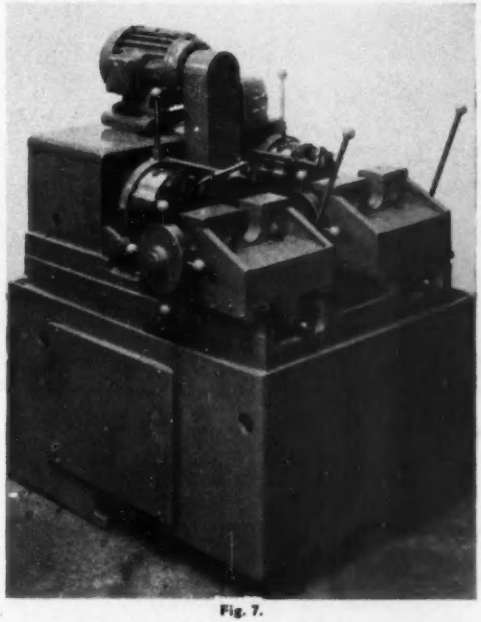

Fig. 7.

carriage front can, however, be replaced by a pneumatic unit for increased production. An automatic or manual length-stop is also available to assist in the correct positioning of work where constant thread lengths are required. The carriage to which the carriage front is secured is of narrow-guide construction, with long

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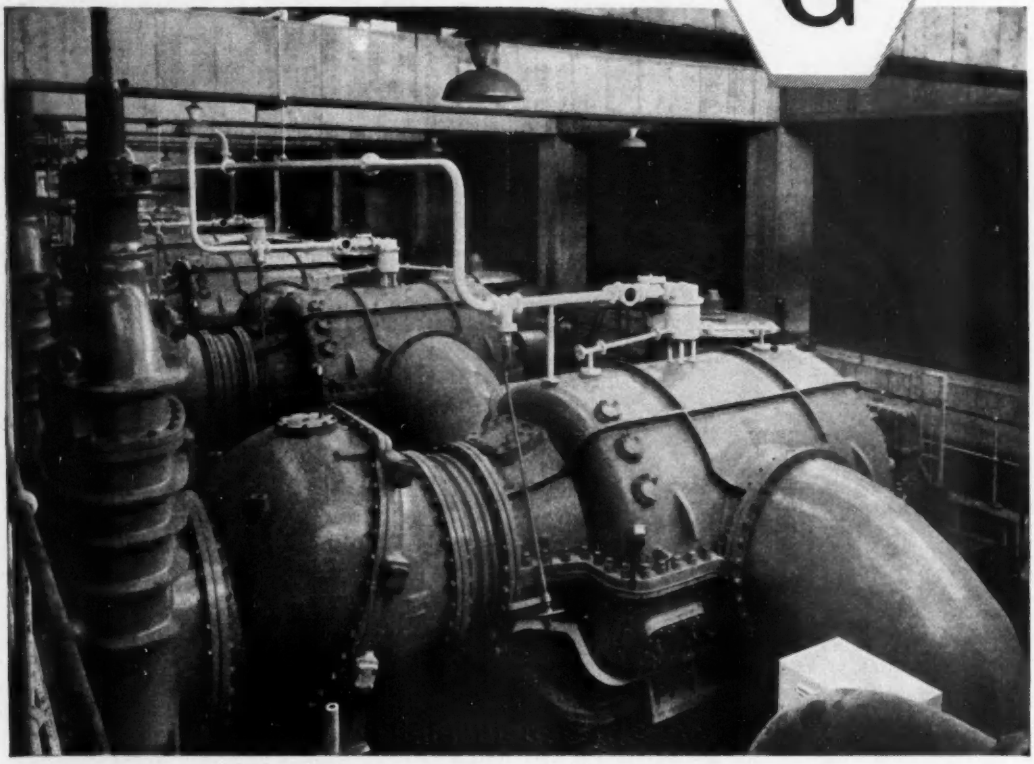

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bearing surfaces carried well forward under the die-head to provide support at the point at which the thread is being produced. A lever traverse of 6 in. is provided with one stroke; as an alternative, traverse can be arranged by means of a handwheel, using a rack and pinion.

Hermann Kolb Maschinenfabrik G.m.b.H.

In addition to a representative range of their products, including pillar and radial drilling machines and gear-grinding machines, Hermann Kolb Maschinenfabrik G.m.b.H., of Cologne, whose U.K. agents are **Stanley Howard Ltd.**, of Saltley, Birmingham 7, exhibited their "Opco 70" optical co-ordinate jig borer. In this machine (Fig. 8), direct measurement of co-ordinates is obtained without the use of any mechanical linkages, but by means of a mirror system and optical projection on illuminated screens with a magnification of ×60.

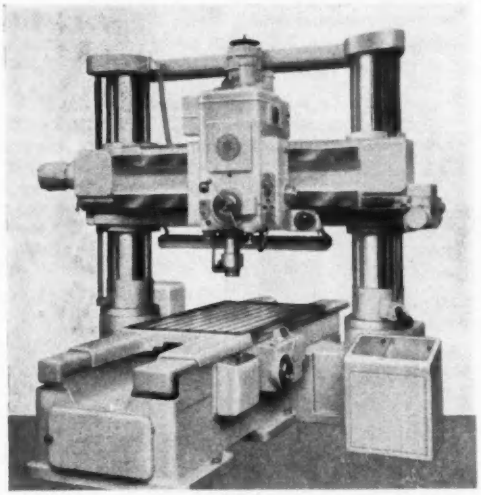

Fig. 8.

Starting from a reference position, the table and boring head are displaced at right-angles to each other in accordance with computed distances, so that any position in the measuring range can be set with extremely high precision. The capacity of the boring head, which is driven by a 7½-hp motor, is the same for all spindle speeds. There are 9 spindle feeds and 24 or 36 spindle speeds, and the maximum drilling capacity in steel is about 2 9/16 in. All controls are centrally arranged and are within easy reach of the operator.

B.P.S. Machinery & Spares Co. Ltd.

Among a range of other equipment, the B.P.S. Machinery & Spares Co. Ltd., of London, S.W.7, exhibited the latest model of the well-known "Whirlmatic" thread-whirling machine, which is a special-purpose machine developed for the quantity production of accurate leadscrews, elevating screws, worms, and other threaded components such as plastic extrusion screws. This machine (Fig. 9) is the latest development in the series of machines produced to utilize the Burgsmüller thread-whirling principle, in which a number of single-point tools mounted in a heavy ring rotate around the work at a high speed, taking a rapid succession of small cuts.

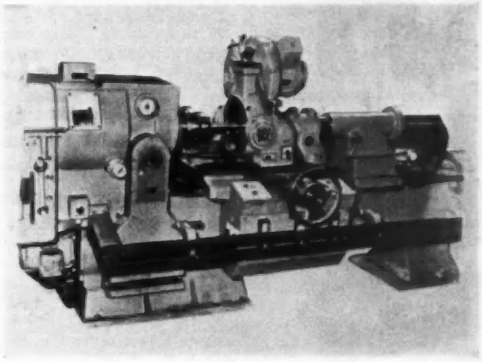

Fig. 9.

The particular machine exhibited also featured a magnetic sensing device for automatic correction, in place of an optical device, as the magnetic type is less sensitive to random light signals. By means of this equipment, correction in a first-off screw can be set up on a board with magnetic blocks, the position being sensed by a reading head which transmits the necessary information to a motor. This motor then moves the leadscrew forwards or backwards to produce the necessary correction. Screws to very close limits can now be produced at high speed by this method.

Bühler Brothers

Representative of their range of more than twenty different types and sizes of diecasting machines, with locking capacities ranging from 5 to 1200 tons for die-castings weighing less than 0·2 oz to more than 65 lb, the Bühler Type H-800 horizontal cold-chamber diecasting machine exhibited by Bühler Brothers, of Uzwil, Switzerland, has a locking capacity of 800 tons and is designed for the production of zinc, magnesium, and aluminium diecastings weighing up to 28 lb. Like all Bühler diecasting machines, whether of the horizontal cold-chamber type or of the vertical cold-chamber or hot-chamber type, this machine (Fig. 10) is a fully self-contained unit, complete with integral hydraulic equipment and toggle-locking mechanism and comprehensive electrical controls.

Important features of the machine, which is powered by a 53-hp motor and is capable of 360 cycles per hour, include extremely large platens made of cast steel and an extra-long opening stroke which can, however, be

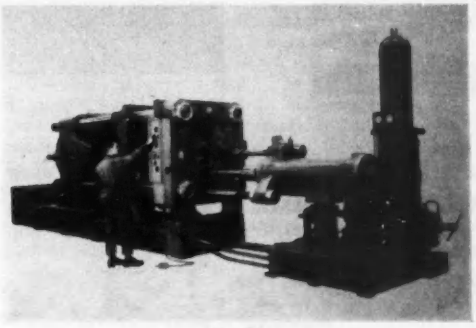

Fig. 10.

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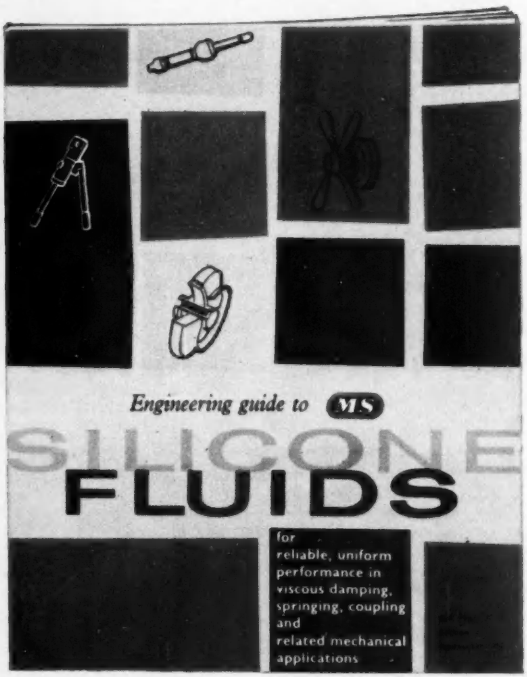

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adjusted mechanically to shorten the operating cycle, when required. Maximum die locking, even under conditions of overloading, is achieved by means of a hydraulically operated special double-toggle mechanism, which can be adjusted quickly and easily to suit a given die height. The speed of die movement is infinitely variable and can be interrupted in any position by means of an emergency switch. Injection takes place in three successive phases, the speed, pressure, and length of each phase being adjustable independently to suit the part to be cast and the alloy from which it is made. The injection cylinder, with a maximum injection pressure of 90 tons, can be hydraulically adjusted to a centre position and to two below-centre positions and is arranged to provide ample space for the use of an automatic ladling unit, if required. The electrical control system, installed in a separate cabinet away from the machine, so as to eliminate the possible effects of vibration on the control gear, makes it possible to select nine different cycling programmes, which can be preselected on a co-ordinate selector board in the control cabinet.

Browne & Sharpe Ltd.

In addition to their Model "A" turret drilling machine equipped with a 3-in. positioning table and trunnion fixture, Brown & Sharpe Ltd. exhibited three of their automatic screw machines, i.e., their Model 2G machine equipped with a third and fourth slide attachment, their Model OOC machine with a 10,000-rpm non-reversing spindle, and their new Model OOB machine, which embodies a number of special features of particular advantage in heavy-duty, high-speed production.

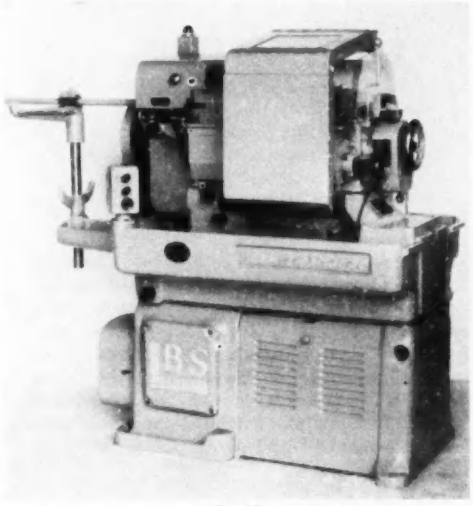

Fig. 11.

The Model OOB automatic screw machine (Fig. 11) has a spindle with a capacity of ½-in. diameter and a wide range of speeds from 35 to 7200 rpm, 256 two-speed combinations being available for a wide assortment of materials. Particularly advantageous in threading operations is the selection of threading-speed ratios available, ranging from 1·6 : 1 to 15 : 1. The turret slide has been designed to provide for additional turning length, a length of 1¼ in. being possible with a lead cam of 5-in. diameter, or 1½ in. with a cam of 5½-in. diameter. Provision has also been made for accommodating larger turret tools. In addition, the turret slide has the desirable feature that indexing is possible at any point on the lead-cam surface, and the lead lever roll follows the cam throughout the indexing cycle. A push-button control station is located conveniently for the operator, and means are provided for inching the machine mechanism.

Rank Precision Industries Ltd.

Exhibits by the **Taylor, Taylor & Hobson Division** of Rank Precision Industries Ltd. included a comprehensive range of instruments for the precision measurement of roundness, surface flatness, squareness, and parallelism. Of these, the Model 2 "Talyrond" roundness-measuring instrument is designed to measure errors in roundness and concentricity on components weighing up to about 1000 lb, including shafts, spindles, and tubes up to 50 in. in length and 10 in. in diameter. Roundness errors down to 0·025 micron are recorded on a polar graph, with radial magnifications up to ×10,000.

Fig. 12.

Other exhibits included the Model D pantograph machine, which is a general-purpose engraving and light profiling machine with a pantograph ratio from 1 : 1 to 16 : 1, and a micro-alignment telescope for the precise setting and checking of alignment, straightness, parallelism, and squareness, with which readings can be taken at any distance up to about 130 ft. Still another exhibit was the "Talymin" comparator, which is side-acting or axial in operation and which provides a convenient means of recording graphically the many small changes in shape and size associated with the testing of parts and the analysis of machine errors.

Of surface-measuring instruments exhibited, the Model 3 "Talysurf" for inspection and standards-room use measures surface irregularities down to 0·025 micron. Measurements are recorded on inkless chart paper, with magnifications of from ×1000 to ×50,000, according to the surface being measured. The latest "Talysurf" instrument is the Model 105, which has been produced to fill the demand for a portable, inexpensive, and versatile means of measuring surface roughness. This instrument (Fig. 12) is suitable for a variety of inspection and workshop applications and enables an inspection rate of from eight to ten parts per minute to be achieved easily. The instrument provides centre-line average readings with a cut-off of 0·08 mm. Four measuring ranges (in English or metric units) are provided, i.e., 0–0·15, 0–0·5, 0–1·5, and 0–5 microns. This instrument is capable of measuring the surface roughness inside a bore of about ¼ in. diameter to a depth of about 11 in.

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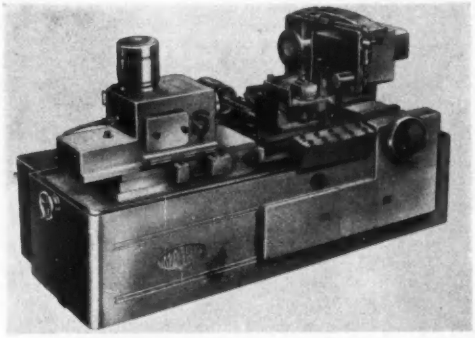
British Industrial Developments

Internal Thread-Grinding Machine

As announced by the sole selling agents in the U.K., the Rockwell Machine Tool Co. Ltd., of London, N.W.2, the new "Matrix TI 1315" internal thread-grinding machine, designed by the Coventry Gauge & Tool Co. Ltd., of Coventry, is intended for the accurate grinding on a quantity-production basis of a wide range of nuts and half-nuts of ball-track or other forms. The maximum workpiece diameter is 13 in., and threads up to 10 in. in diameter can be ground. Apart from loading and unloading components, the machine is fully automatic. A single ribbed grinding wheel, automatically diamond-dressed at preselected intervals, is used. Single-pass or multi-pass grinding can be carried out, the maximum number of passes being 24 and the total automatic wheel infeed being ¼ in. The special diamond dressing unit is mounted on a swivelling cradle, so that the wheel can be accurately formed with the wheelhead inclined at the helix angle of the thread being ground. Wheel-dressing can be effected before or after the final grinding pass. Rapid withdrawal of the wheelhead to the loading and dressing position is pneumatically operated, as also is automatic compensation for wheel-dressing.



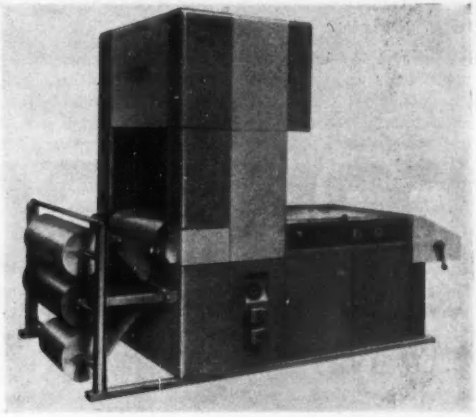
On full nuts, the grinding action is continuous, wheel infeed taking place at each work-slide reversal. When grinding half-nuts, the wheel feeds into the stationary workpiece to the preset depth, the work spindle then revolves, and the work-slide traverses. At the end of the traverse, the wheel retracts clear of the work and the work-slide returns. To permit easy loading and unloading, the wheelhead is automatically retracted to its rear position when a workpiece is finish-ground. Two types of grinding-wheel spindles are available, i.e., belt-driven or high-frequency. The former, which is driven by a 5-hp motor, has speeds of 15,000 and 18,000 rpm, while the latter has infinitely variable speeds from 12,500 to 40,000 rpm. The maximum grinding-wheel diameter is 3 in. A swivelling movement is provided for the wheelhead unit to permit right- and left-hand threads with helix angles up to 15 deg. to be ground. The normal maximum thread length ground is 5 in., but this can be increased to 7 in. with a special wheelhead design, although this limits the maximum helix angle to 10 deg.

The workhead is driven by a 1½/3-hp motor, providing 7 spindle speeds. The pitch of the thread ground is determined by interchangeable leader bars and nuts, the same bars and nuts being used for right- and left-hand threads of identical pitch. The workhead is mounted on a sub-slide and can be positioned longitudinally relative to the grinding wheel, facilitating the grinding of short threads in long components. The maximum distance from spindle nose to grinding-wheel centre is 15½ in. The workhead spindle, which has a 2-in. bore, can be indexed for 2, 3, 4, 5, and 6-start threads. An adjustment to control parallelism is provided, as also is a side-cut control for aligning a pre-roughed thread with the grinding wheel. Coolant is delivered through the workhead spindle and also externally to the grinding wheel. A delivery pipe is also provided at the wheel-dressing position.

Fully Automatic High-Frequency Machine for Welding Plastics

Of compact design and consisting basically of a press and a generator, the new "Acme" Model No. 200 fully automatic high-frequency welding machine for plastics, announced by H. F. Industrial Services Ltd., of London, N.22, has a power rating of 6 kW, and a standard platen size of 24 in. between the press guides and 30 in. in the direction of traverse, though other sizes can be supplied to special order. The machine is capable of handling P.V.C. materials in thicknesses of from 0·004 in. upwards. A contributory factor to the high production rate of this machine is the use of very high frequencies, which also result in the elimination of flash. The high-frequency generator is a development of the company's original cavity type, while the welding electrodes and oscillator valve are water-cooled. Stabilized metal rectifiers are used, and these, like the use of a water-cooled oscillator valve, are conducive to considerable economy insofar as replacement costs are concerned.

The transfer mechanism is electrically driven and is fully interlocked with the press and the high-frequency generator. Separate timers are incorporated for the weld and dwell cycles. The length of traverse is adjustable



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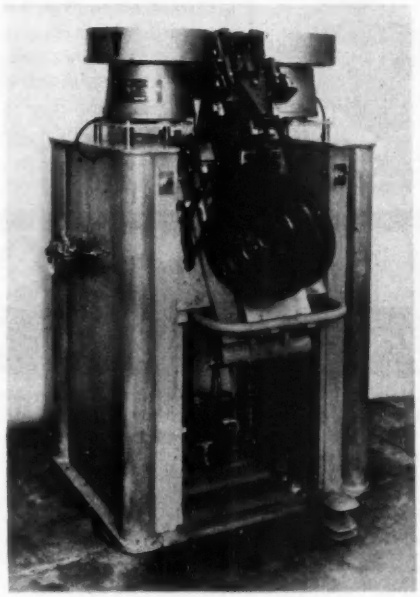
between 6 and 30 in., and repetitive accuracy of transfer is stated to be exceptionally high. A three-up reel is included as standard and is built in as an integral part of the machine. Reels up to 24 in. in width and 11 in. in diameter (or two reels of 15 in. diameter) can be accommodated, and replenishment of a roll can be carried out in less than 90 sec. Control is extremely simple, a three-position and "off" switch providing for operation of the press only, for transfer only, and for continuous automatic operation. Inching down of the electrode by means of a push-button is also provided, thus making mounting and levelling of large electrodes, as well as last-minute checking and positioning of the articles to be welded, a simple matter. The maximum press stroke of 6 in. is adjustable to minimize the time cycle, but full opening can be achieved by pressing an overriding push-button. Operation of an emergency button during any part of a cycle instantaneously removes the high-frequency power, fully opens the press, and stops the transfer mechanism.

An interesting feature of the machine is that welded articles are not separated from the barrier until they are "frozen" in their flat form, thus ensuring reliable stripping of the finished product, irrespective of whether it is of thin or thick material. In addition, freedom from snarling up around the stripping rollers or blades, as well as improved finish of the welded edge, is achieved.

Semi-Automatic Tyre-Valve Inserting Machine

Stated to be the first of its kind, a new semi-automatic tyre-valve inserting machine, supplied to Standard-Triumph International Ltd., of Coventry, by The Hymatic Engineering Co. Ltd., of Redditch, Worcs., automatically selects the correct type of tyre valve to be inserted and then feeds it to the loading position. Operation of a foot-valve causes the appropriate valve to fall into the loading position, a loading arm picking up the valve, passing it through a pair of soaping brushes, and inserting it into the wheel.



The machine will insert valves of $\frac{1}{2}$ and $\frac{5}{8}$ in. sizes, which are placed separately into two bowl feeders on top of the machine. After automatic sorting and orientation, the valves are fed into separate single tracks before finishing up at two escapements. When a wheel is loaded on the inclined table at the front of the machine (shown in the illustration with the guards removed), it is turned radially until a spring-loaded plunger engages in the valve aperture. The depth to which the plunger sinks engages the appropriate escapement and allows a valve to be fed down to a pair of spring-loaded clamps. When the correct valve is in the clamp, the foot-valve is operated, causing the hinged loading arm, carrying a probe, to swing over radially. The arm engages the valve on the end of the probe and opens the clamps, thus leaving the valve sticking to the end of the probe. At the same time, the valve is lubricated between two soapy brushes and then the arm continues its downward path to insert the valve into the valve aperture, after first contacting the end of the valve-selection plunger.

When the foot-valve is released, the arm swings back and the machine is ready for operating again. As a safeguard in case of the possible stoppage or interruption of the cycle, a special reset button is fitted to the machine. This button will swing the arm clear, close the clamps, and make the equipment ready to start another cycle. A tank at the rear of the machine is filled with soaping solution for lubricating the valves, the supply to the brushes being regulated by a metering valve fitted to the underside of the tank. A certain amount of this solution passes through the brushes, and this is collected in a cylindrical tank fitted below the loading table.

Ultrasonic Sensing and Switching System

A new non-contact sensing and switching system, using an ultrasonic sound beam (38 kcs), is now available from Westool Ltd., of St. Helen's Auckland, Co. Durham. The system, designated "Westool Sonac", is produced by Westool under licence from the Delavan Manufacturing Company, of West Des Moines, Iowa, and is expected to have a wide application in industry for automatic counting, package routing, level control, positioning, sorting, and numerous other control operations. The system can be used to detect solids or liquids, opaque or transparent objects, metallic and non-metallic materials, including fibres, cloth, and paper, or, in fact, any material that can cause a substantial change in the sound path. In addition, the beam can be arranged to be several feet in width or to work through holes down to about 0·03 in. in diameter.

The system consists of three major parts, i.e., a control unit containing a transistorized amplifier, a plug-in output relay, and a power supply, and two hermetically sealed acoustic sensors. These two matched sensors convert electrical energy to ultrasonic energy and *vice versa*, one sensor acting as a transmitter and the other as a receiver. Electrical energy from the control energy is converted to ultrasonic energy by one sensor, which emits a continuous ultrasonic beam, while the second sensor receives the beam and converts the ultrasonic waves to electrical energy which is, in turn, sent back to the control unit, thus providing circulation around a closed loop. The ultrasonic beams will follow almost any path, provided that nothing is directly in front of

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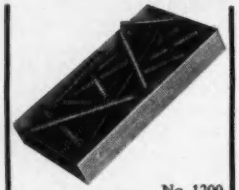

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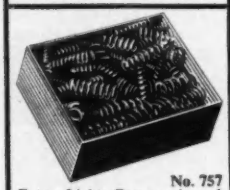

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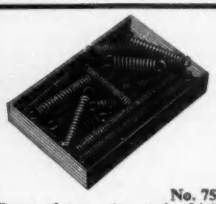

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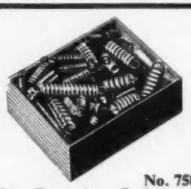

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them. Consequently, the units can be remotely located and the ultrasonic beam conveyed to the work areas, even around corners, with flexible tubing.

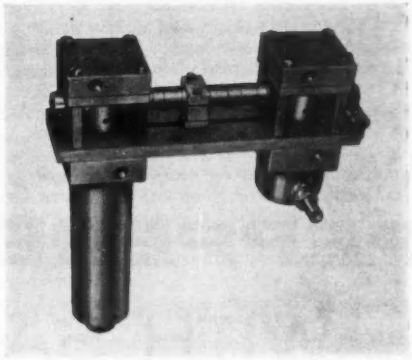
Special sensors are available for converting the sound waves down to a small area of transmission through flexible rubber hose or metallic pipe to reach areas too confined for the general-purpose sensor installation. In addition, special focalizer sensors are available for producing beams of a very narrow angle and for receiving sound energy from a very narrow angle.

The system can be used in two ways, i.e., using a direct-path beam and a reflective-path beam. In the direct-path method, an obstruction between the sensors breaks the acoustic path, thereby de-energizing the output relay, which operates the desired external function, such as a light, buzzer, or switch. Although ultrasonic waves are transmitted from one sensor to the other sensor at an angle of approximately 50 deg., an object large enough to cover the active area of the second sensor (1-in. diameter) will break the beam for short path lengths. The direct-path method can also be used to sense the removal of an object from the beam. With the object obstructing the beam, the output relay is de-energized. When the object is removed, the acoustic path is completed, energizing the relay.

In the reflective-path method, the sensors are arranged to provide a reflective beam, which can also be used in two ways, i.e., with the relay energized to sense objects, or with the relay de-energized to sense the removal of objects from the beam. In this method, the sound waves emitted from one sensor are reflected from an object to the second sensor to provide the acoustic path. When the object is removed from the path, the relay is de-energized. Conversely, when objects establish a path, the relay is energized. The reflection method is particularly advantageous for counting or sensing small objects.

Pneumatic Ratio Totalizer Relay

When one or more flow-signal transmitters and a pressure transmitter are employed in a control system, it is necessary to use one or more pneumatic relays in which the various signals can be combined to produce the final action signal for the variable under control. A new ratio totalizer relay, introduced by Hagan Controls Ltd., of London, S.W.1, has been specially designed for this purpose, and is stated to be exceptionally sensitive and versatile. In its standard form, the relay can perform simple addition, subtraction, comparison, multiplication, division, and averaging of two input signals. Furthermore, it can provide control action with or without



integral (reset) action, derivative (rate) control action, or, when used in pairs, can select the higher or lower of two input pressures.

The relay, which is extremely accurate and reliable, essentially consists of three input or receiving chambers containing sensitive diaphragms, and a fourth transmitting chamber containing a pilot valve and diaphragm. The four chambers are mounted in oppposing pairs, interconnected by a balance beam carried on a thin sheet-steel fulcrum whose position is adjustable over wide limits. The output from the relay equals the algebraic sum of the moments of the three input-pressure signals. When fitted with a spring barrel, the relay can also provide proportional control against a fixed set point, with or without reset action, can reverse an input loading pressure, can split an input into two ranges, can convert one signal range to another range, or can provide pneumatic toggle-switching action. The fitting of bellows elements in place of diaphragms in the input chambers increases the pressure range that the relay can accept and the range of its multiplication and division capabilities.

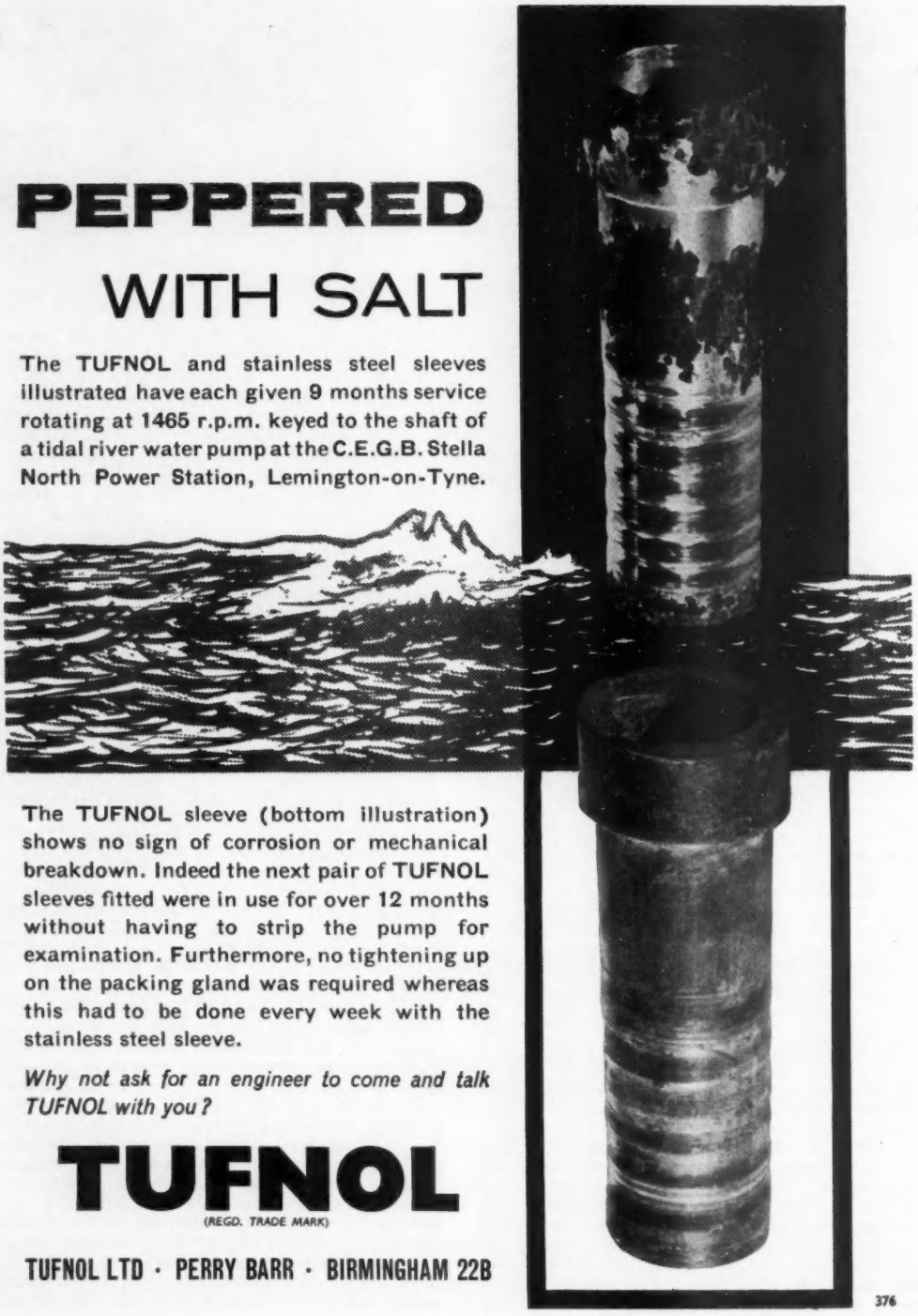
Self-Contained Firedamp Detector

Measuring only $8\frac{1}{4} \times 3 \times 2$ in. approximately and weighing less than 3 lb, the new M.S.A. general-purpose methanometer, announced by the Mine Safety Appliance Co. Ltd., of Glasgow, is an accurate, robust, and compact self-contained, non-automatic mine-firedamp detector with a range of from 0 to 5% methane. The instrument is extremely easy to operate, all that is required being to depress a button on the front of the stainless-steel case while a sample of the air to be tested is passed through the methanometer by means of a rubber aspirator bulb.

The filaments used are very stable and are of a type developed by the Safety in Mines Research Establishment. Because filament life is extremely long, no provision for replacement has been made. The flow system and electrical circuit, with the exception of the calibration resistance, are encapsulated in an epoxy resin contained in a nylon moulding, another nylon moulding forming the battery container. The indicating meter, which is protected by an armoured-glass window, is separately mounted on rubber. The instrument is powered by two mercury cells, enabling at least 6000 tests to be made with one set of batteries under normal working conditions. The state of the batteries can be checked at any time by depressing the meter button and closing a microswitch located in a recess at the back of the case. Should the

PEPPERED WITH SALT

The TUFNOL and stainless steel sleeves illustrated have each given 9 months service rotating at 1465 r.p.m. keyed to the shaft of a tidal river water pump at the C.E.G.B. Stella North Power Station, Lemington-on-Tyne.



The TUFNOL sleeve (bottom illustration) shows no sign of corrosion or mechanical breakdown. Indeed the next pair of TUFNOL sleeves fitted were in use for over 12 months without having to strip the pump for examination. Furthermore, no tightening up on the packing gland was required whereas this had to be done every week with the stainless steel sleeve.

Why not ask for an engineer to come and talk TUFNOL with you?

TUFNOL
(REGD. TRADE MARK)

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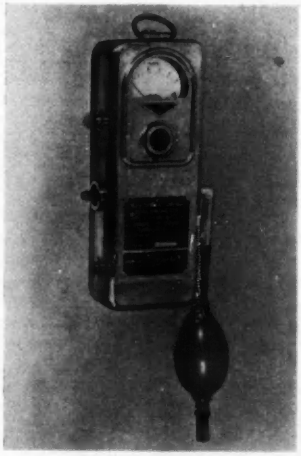
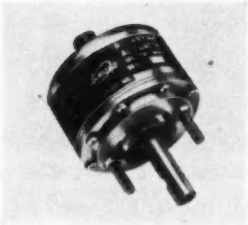
376



resulting meter reading fail to register a predetermined level, it is a sign that the batteries should be replaced. The instrument is self-zeroing and self-compensating for changes in battery voltage over the operating range. Normal changes in atmospheric pressure, temperature, or humidity have no effect on the accuracy of the readings. Special provision has been made for using the instrument with a sampling probe, an accessory designed for obtaining samples from roof level in high roadways or other inaccessible places.

Miniaturized Pneumatic Rotary Actuator

As announced by NSF Ltd., of London, W.C.1, the licensees of Ledex Inc., of Canton, Ohio, U.S.A., the Series 50 pneumatic rotary actuator is a miniature medium-speed unit which makes it possible to control economically a variety of machine tools and operations, including valves, clamping devices, indexing, and conveyor-belt gating. Weighing about 8 oz, and measuring about 2 in. in length by 1½ in. in diameter, the Series 50 actuator has a high torque output for its size, providing a torque output of 6·5 lb-in. for a maximum operating air pressure of 120 psi and a 90-deg. output-shaft rotation. A range of other sizes, developing torques between 1·35 and 94 lb-in., will be available shortly.



The actuator operates on the principle of the conversion of linear movement to rotary movement through a system of balls running in suitably inclined races. The integral rotary shaft, i.e., the driven member, can be directly coupled to the load, thus dispensing with costly linkages. Torque is uniform throughout the rotary stroke, no compensation being necessary. Speed is dependent on load, the normal actuating time of the Series 50 unit without load and at 120 psi being from 30 to 40 milliseconds for completion of the 90-deg. stroke. The air displacement of the actuator is only 0·16 cu. in., and the piston stroke is 0·78 in.

Safety in operation is ensured, owing to enclosure of all working parts, which mainly consist of the short-stroke piston and the integral rotor plate and output shaft. Shaft seals are not employed, so that there is little to deteriorate or wear, while special air-lines are unnecessary, as the unit is self-lubricating. Also, overheating cannot occur, so that the actuator can remain indefinitely in the fully operating position.

Plant for Coating Quartz Crystals

Ease of operation and control are the essential features of a new plant designed by N.G.N. Electrical Ltd., of Accrington, Lancs., for the rapid coating of quartz crystals during the final frequency-fixing operation. For mobility, the plant is mounted on castors and is fixed rigidly in position when in use by means of speedily operated screw-jacks.

The crystals are mounted in twin chambers closed by stainless-steel covers, each being pumped alternately to an indicated vacuum of less than 0·5 micron of mercury. This operation is completed in less than 15 sec by a combination of rotary and diffusion vacuum pumps operated by a four-position control switch. A detachable ring for mounting the crystal holders and filaments is provided in each chamber. A further four-position rotary switch controls pumping, air admittance, and evaporating filament supply to the chambers. The controls are arranged so that each chamber can be operated alternately by simply turning the switch through 90 deg. The remaining two positions on the switch enable both chambers to be pumped together or isolated under vacuum during shut-down or rest periods.

Low-capacity lead-through electrodes are provided in each chamber to connect the crystal and the frequency-checking apparatus. Heavy-duty electrodes carry the evaporating filament supply into the vacuum chambers. The four-position switch is fitted with spare contacts to enable the user to install the desired method of evaporation control.

"any other form of water heater would have been extortionate"

and not so convenient, immediate, or economical.

The Works Director was talking about Leonard steam water heaters which, from available steam and cold water lines, provide abundant thermostatically-controlled water at low cost.

It all began with a note to

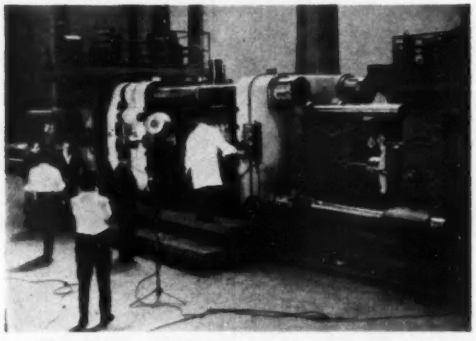
WALKER CROSWELLER AND COMPANY LTD., CHELTENHAM, GLOUCESTERSHIRE.

New Materials, Processes, and Equipment

2200-Ton Cold-Chamber Diecasting Machine

As announced by the British agents, Alexander Cardew Limited, of London, S.W.1, a new 2200-ton cold-chamber diecasting machine, made by Triulzi, is the largest of its kind in the world. The machine was recently shown in operation at the company's works in Milan, involving the production of aluminium-alloy cylinder-blocks for the Russian 2½-litre "Volga" car. Each casting weighed about 48 lb gross, with slug and runners, and about 40 lb nett after trimming. The special die weighed about 14 tons and was operated at a temperature of 230° C in the middle of the cavity. Now that these tests have been completed, the machine is being shipped, complete with die, to Russia.

The minimum cycle recorded during these tests was approximately 4 min, with an actual cooling time of 35 sec. However, a great deal of time was spent in ensuring thorough lubrication of the die and, when the die is run in, the Russians are satisfied that they can obtain 20 castings per hour from the machine, using only three operators, i.e., one for normal running of the machine, one for removing the casting from the transfer system, and one for looking after the "Dosomatic" automatic ladling furnace. Two further machines of this type are scheduled for delivery to the Volga factory in Russia. In this connection, it should be noted that the blocks produced during these tests were for a four-cylinder engine. As, however, the machine has adequate capacity for producing larger castings, plans for producing V-8 cylinder-blocks on the same machine are already under way.



The platens of the machine are approximately 6 ft square, with 51 in. between tie-bars. The die opening stroke is about 5 ft. The machine cycle is automatically controlled from clamping to transfer of the casting, including dosing of the metal into the cold chamber, core movement, and injection. The actual transfer mechanism consists of a fabricated frame, pivoting on the outer edge of the die opposite to the machine operator. The mechanism is driven by a rack and pinion to come into position just below the cavity on the moving piston, so that the ejectors push the casting out onto the frame. The rack-and-pinion mechanism then swings the casting clear of the die.

The locking system consists of four radially positioned wedges, locking into an annular ring around the main column at the end of the clamping stroke. This is followed by pressurization of a ram with a very small stroke (less than 1 in.) at the front of the main column. As the main column is moved forward by jack-rams, the system is highly conservative in water requirements. The injection pressure is infinitely variable between 80 and 170 tons, and the injection capacity is over 100 lb of aluminium alloy.

The "Dosomatic" ladling furnace is a unit comprising a furnace and an automatic dosing device specially designed for use with cold-chamber machines, so as to enable automatic cycling to be obtained. To ensure perfect dosing, the quantity to be ejected each time can be accurately preset, ejection of molten material and its loading into the sleeve being effected either manually by a push-button, or automatically. To avoid any oxidation of the molten material, an inert atmosphere is maintained inside the dosing device.

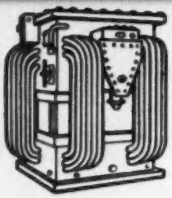
Cold-Immersion Paint Stripper

A powerful cold-immersion paint stripper, capable of removing rapidly even the most adherent paint films, including stoved epoxy-resin, acrylic, alkyd, amino, and polyurethane enamels, merely by cold-dipping, followed by hosing and plunge-rinsing or brushing off, has been developed by Grant & West Ltd., of Guildford, Surrey. Designated "Chemiclene No. 415", the stripper can be used in an ordinary mild-steel tank and is supplied with its own inhibited anti-corrosive water seal to prevent evaporation. Although it contains strong solvents and is mildly acidic, so that operators should wear protective clothing and eye and face shields, it is stated to be much safer to use than many other paint strippers. A special grade of stripper is available which does not leave any residual smell on the metal treated.

In operation, the components to be treated are submerged completely in the stripper below the sealing layer and are then withdrawn slowly to effect drainage and thereby to reduce drag-out loss of the solvents before passing through the water seal. The water seal is maintained at about 10% of the total depth of liquid in the tank and can be topped up simply by the addition of clean cold water to which has been added about 1% of the No. 415 inhibitor.

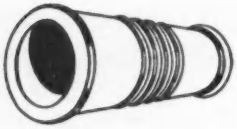
Electronic Bend-Angle Selection Equipment

Stated to speed up production and to afford considerable savings in the costs of short-run bending operations, a new electronic bend-angle selector, designated "Dial-A-Bend", has been developed by the Pines Engineering Co., Inc., of Aurora, Illinois. With this equipment, an untrained operator can programme bend angles from blueprint specifications or records from previous set-ups. Correction factors, including springback, are accommo-



from transformers

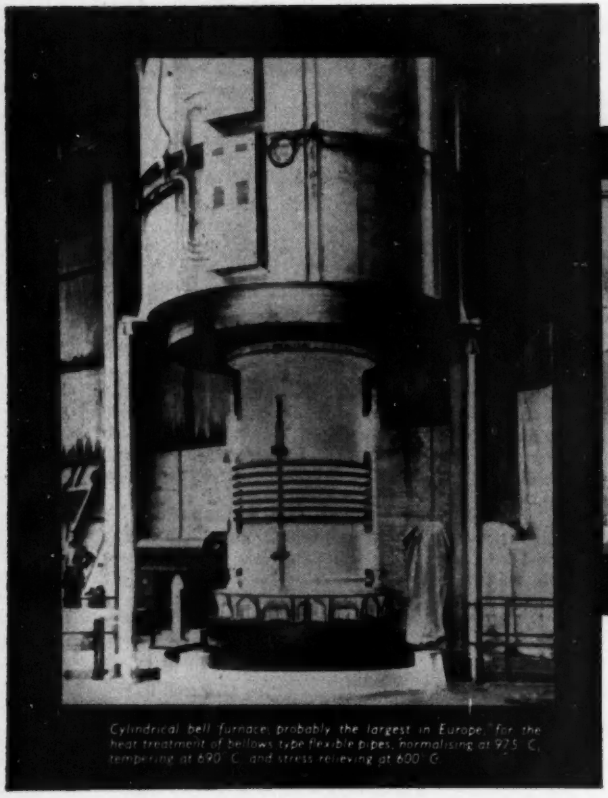
to bellows



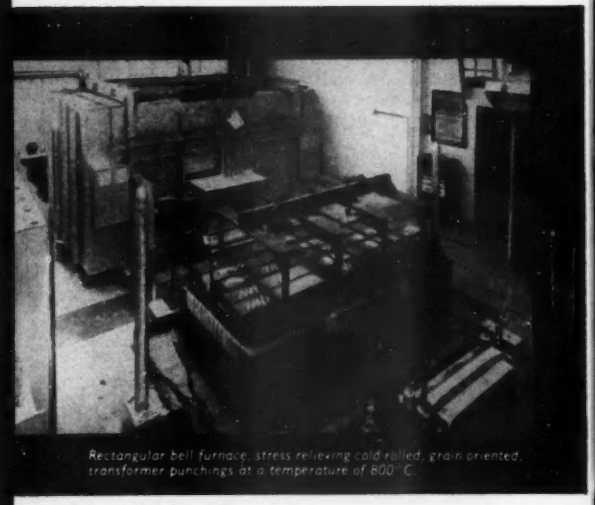
the relief of stresses demands

EFCO

BELL TYPE FURNACES



Cylindrical bell furnace, probably the largest in Europe, for the heat treatment of bellows type flexible pipes, normalising at 975° C, tempering at 690° C, and stress relieving at 600° C.



Rectangular bell furnace, stress relieving cold rolled, grain oriented, transformer punchings at a temperature of 800° C.

When you need to heat treat ferrous or non-ferrous metals, in strip or wire or fabricated form, in rectangular or cylindrical furnaces, in controlled atmosphere or in vacuum — choose an Efco Bell.

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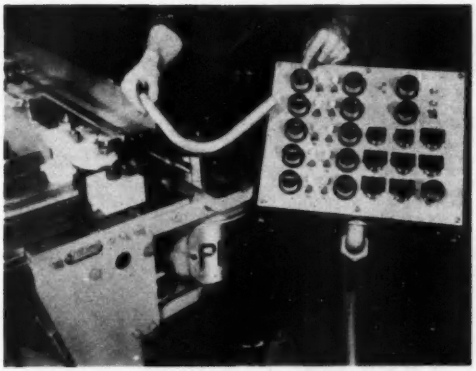


dated by setting special compensator dials, each bend angle then being "dialled" in the normal programming sequence on individual angle dials on a panel. Up to ten different angles can be programmed on rotary bending machines, and up to fifteen angles on bending presses.

The equipment operates on the principle of matching electrical impulses from signal potentiometers, which can easily and quickly be set to produce the required degree of bend. When a swinging arm rotates to the proper angle, the control matches the angle-dial setting, and the bending arm is stopped, terminating the bend. Each angle dial is equipped with a three-digit micro-dial graduated to tenths of a degree to provide maximum precision in bend-angle settings. The two compensator dials in the panel provide for dialling the necessary overbend to allow for springback and other factors influencing the bend angle. One of these dials applies a constant degree of overbend to all preset angles, while the other dial adds a percentage of overbend to each angle to ensure workpiece accuracy. Each of the angle dials is arranged with an "off/on" toggle-switch and indicator light. This switch must be in the "on" position to include the bend in the sequence, thus permitting advance programming of more than one job by switching on only the dials desired for the specific sequence.

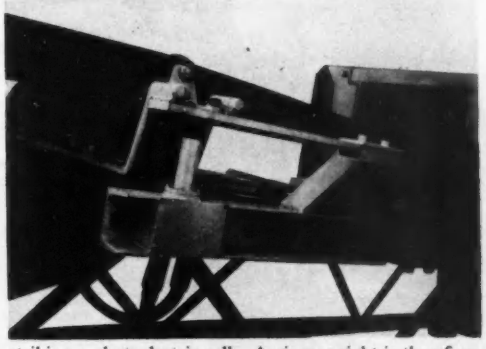
Continuous Electronic Weigher for Conveyor Belts

The Craven continuous electronic weigher, announced by Craven Electronics Ltd., of Bingley, Yorks., automatically weighs and records the weight of material on a conveyor belt, presenting the information on a counter in units of weight to suit any requirements. The unit is accurate to within 0·5%, even with belts that are badly loaded and out of track, and inaccuracies due to friction cannot arise, as there are no wearing parts. The unit can easily be fitted to belt conveyors of any make or type and occupies virtually no extra space on the conveyor. Headroom is not restricted in any way, and errors due to spillage are completely eliminated. All external circuits operate on low voltage, and arrangements can readily be made for remote instrumentation.

The equipment comprises three basic units, i.e., a weighing section, a tachometer generator, and an integrating and totalizing unit. The weighing section (illustrated) consists of two cantilever arms, positioned one on either side of the conveyor. These arms carry a weigh-idler at one end and are attached at the other end to the side frames, which, in turn, are bolted to the conveyor stringers. Any material on the conveyor belt deflects the arms in proportion to weight, and this deflection is transmitted to the armatures of differential transformers which produce a small alternating voltage whose amplitude varies linearly with the deflection, i.e., with the weight of material on the conveyor belt.

The function of the tachometer generator, which is driven from the underside of the top belt, is to produce the energizing current for the weighing transducers, the weight and belt speed being multiplied to produce a resultant flow-rate signal. The transducers are adjusted to give zero signals when the conveyor belt is running empty.

In the integrating and totalizing unit, the signal from the weighing section is amplified and supplied to an integrator motor, linear and stable amplification being achieved by negative feedback. The integrator motor incorporates a disc which rotates at a speed directly proportional to the signal and therefore proportional to the instantaneous deflection of the weigh-idler section and the belt speed. The integrator motor produces pulses whenever the disc rotates, e.g., when material is passing over the conveyor, this being accomplished by means of light passing through holes in the disc and

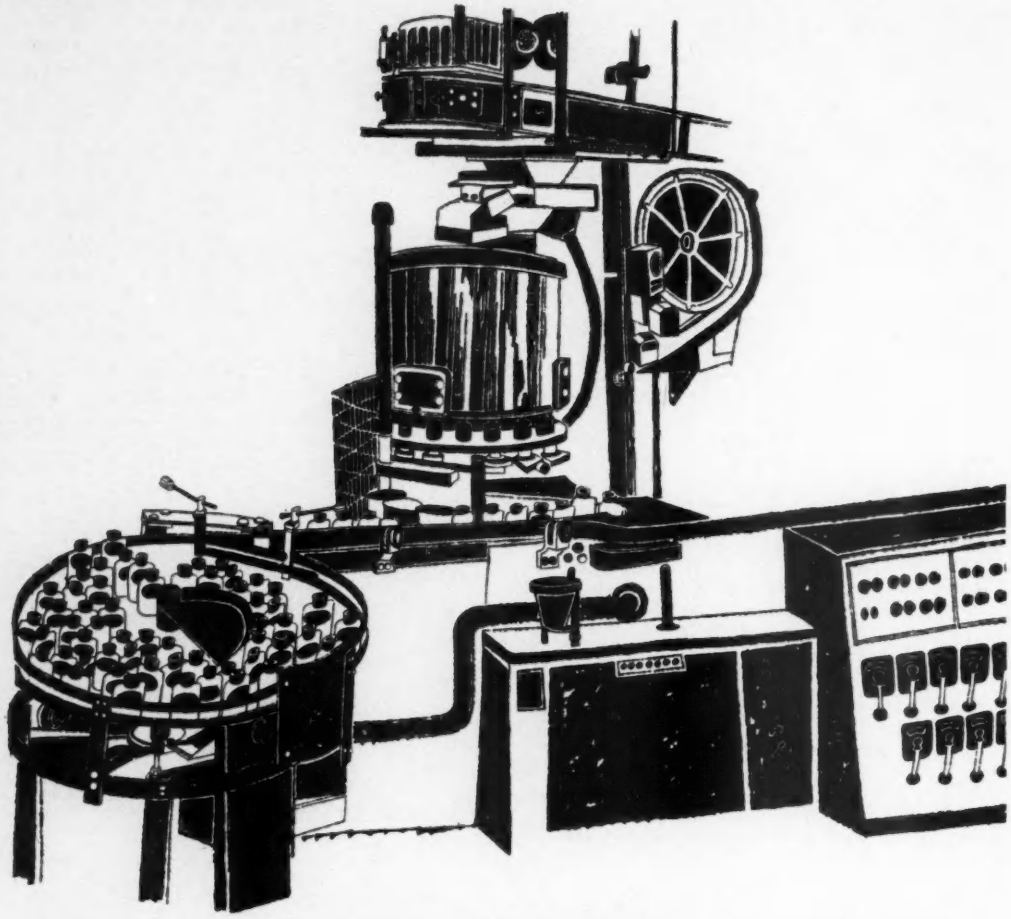


striking a photoelectric cell. A given weight is therefore made to produce a definite number of pulses in a given time. A printing counter is actuated by the pulses from the integrator motor and records the flow rate of the material over the conveyor. Printing facilities are available on a tear-off paper strip, and the standard counter will give a maximum reading of 999,999. A low-level cut-out is incorporated to eliminate counting pulses in cases where there is any variation in the weight of the empty belt.

Miniature Noiseless Oil-filled Synchronous Timer Motors

Stated to provide an entirely new concept in the design of synchronous timer motors, a new motor developed by Lake City, Inc., of Crystal Lake, Illinois, a subsidiary of the Controls Company of America, features a special method of sealing all moving parts in oil. Complete sealing is effected by a specially designed spring-loaded packing gland which prevents the oil from worming out of the housing when the motor is operating. The key element of the packing gland is a neoprene "O" ring, which is held under constant pressure by a spring, thus sealing in the oil effectively.

Measuring only 1 ¼ in. in diameter, the new timer motor is one of the smallest ever developed, and is expected to have a wide range of applications in industrial automation control systems, computers, office equipment,



THE MONEY THAT MANAGEMENTS SAVE THROUGH MOBIL ECONOMY SERVICE

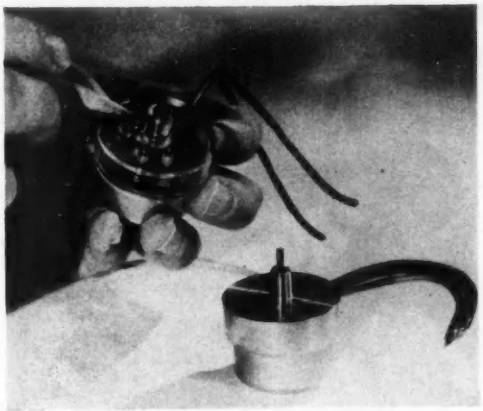
More than £3,000 saved in a year at Reckitt & Sons Ltd

RECKITT AND SONS LTD of Hull, asked Mobil to suggest improvements in the maintenance and lubrication systems at four of their factories. Mobil advised using a card index system to ensure regular and correct lubrication, reducing the number of oils stocked, reclamation of used oil, and several other schemes of preventive maintenance and purchasing rationalisation.

In one year, after applying Mobil's recommendations, Reckitt made a direct saving of over £3,000. A further immediate saving of over £900 is probable.

World-wide experience of industrial lubrication has been built up by the Mobil Organisation over 90 years. The Reckitt case is one of hundreds in which the recommendations of the Mobil Economy Service have successfully cut lubrication and maintenance costs. **Specialist knowledge methodically applied** is the value of the Mobil Economy Service. The total lubrication requirements of a business and the minimum number of lubricants in the smallest quantities it needs must be assessed. And everyone concerned must know how to achieve the best lubrication results with the greatest economy of labour. These are tasks undertaken by the Mobil Economy Service —and the big savings resulting from its recommendations are a measure of its success.

Mobil
ECONOMY SERVICE

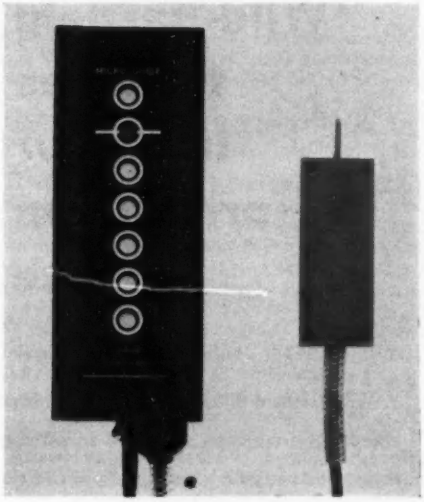


home appliances, and military control devices. In addition to the virtually complete elimination of wear on moving parts and the consequent assurance of almost unlimited continuous operation, the special mineral-oil lubricant used in the motor housing renders the motor completely silent. Other components of the motor, also submerged in the oil, include the variable pole arm, which provides starting reliability when the rotor poles are stopped at dead centre, and a magnetic directional device which maintains proper rotation of the gear when the motor is energized.

Simple System for Monitoring the Final Stages of Machining Operations

Designed to cater for the need for a simple and inexpensive method of monitoring and clearly indicating the final stages of machining operations, the "Micro-Guide" system announced by Paramatic Development Ltd., of Derby, enables repetition work to be carried out on many types of machines at higher speeds and with closer precision by semi-skilled operators. The system is applicable to a wide range of operations involving continuous repetition or comparisons to fine limits, and can easily be adapted to such applications as selective sizing and grading to fine limits, to the continuous monitoring of fully automatic machining processes, to repetition centre-lathe work, and to the accurate positioning of work in jigs and fixtures. In addition, it enables old machines to be employed on close-tolerance work normally beyond their capacity.

The complete installation for each machine essentially comprises an indicator panel and either one or two special micro-heads with their associated connecting leads. The micro-head (shown on the right of the illustration) is a compact sealed unit just over 4 in. in length, with a gauge-lever projecting from one end and a connecting cable from the other end. The micro-head magnifies the slightest movement of the gauge-lever and then selectively causes appropriate lights to appear on the indicator panel. As can be seen from the illustration, the panel has seven indicating windows arranged vertically, the illumination of each in turn representing predetermined stages in the finish of a machining operation. Thus, with a normal setting, full rough cuts can be taken until illumination of the green window at the bottom of the panel indicates arrival to within 0·025 in. of the final true size, this window remaining illuminated during the advance towards 0·005 in. from the final size. At this stage, successive advances of each 0·001 in. are indicated by the illumination in turn of the four amber windows above the green window, until the true size appears in the next (red) window. An overrun of 0·001 in. beyond this true size causes a blue window above the red window to be illuminated and, at the same time, an audible warning is operated, emphasising that the work has proceeded too far. If desired, the unit can be arranged to cater for still finer limits.



A typical example of the application of this system is its use in a turret lathe, in which a micro-head is fitted to the machine in such a position that the normal six preset stops automatically engage the micro-head lever, instead of the fixed back-stop. With these stops slackened off, each particular machining operation is carried out to the required dimension and, with the tool left in the position of the final cut, the appropriate stop is adjusted onto the lever until the red light appears, after which it is locked. When all the machining operations have been dealt with in this way, the workpiece can be reproduced by a semi-skilled operator, who merely watches the lights. Another micro-head plugged into the same indicator panel can be placed on the cross-slide for actuation at predetermined forward or backward positions, so that all machining operations can be monitored.

Centrifuge for Separating, Cutting, Processing, and Tempering Oils

Claimed to be considerably cheaper than any existing equivalent type, the new Model 3C oil-separating centrifuge announced by R. Cruickshank Ltd., of Birmingham 1, is designed to separate rapidly and efficiently cutting oils from machined swarf and processing and tempering oils from components, the oil being saved for immediate re-use. In addition, the machine is of compact dimensions, measuring only 28 × 34 × 40 in. high, and can be operated by entirely unskilled personnel.

In operation, the swarf or other material is loaded into a perforated metal basket which is then placed on a drive-dog in the base of the machine. As soon as the

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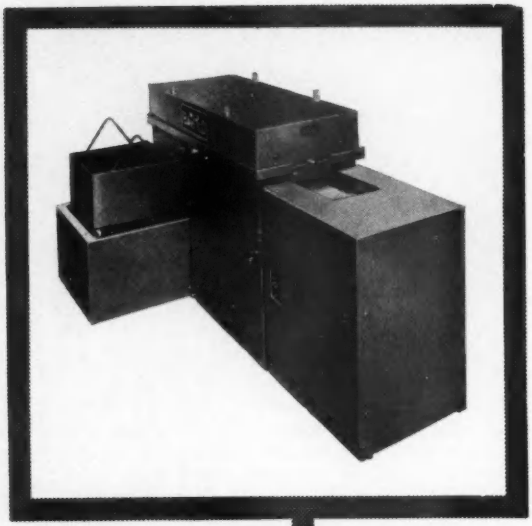

A Wild-Barfield furnace will bring immediate advantages. It speeds up production and helps to cut costs by eliminating delays and wasteful handling. Built to the highest standards of workmanship, these furnaces offer consistent results and minimum maintenance. The Wild-Barfield Research Department is available at all times to advise you on your heat-treatment problems.

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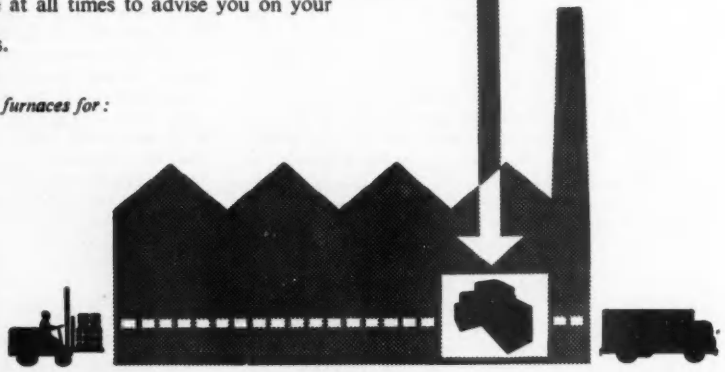

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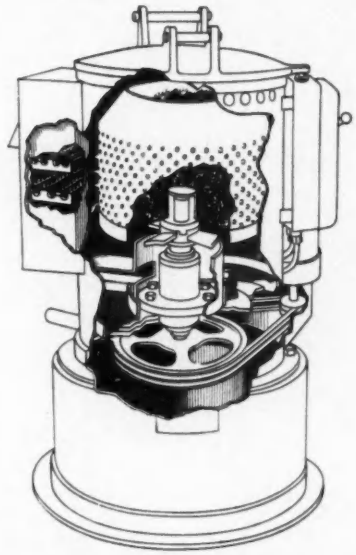
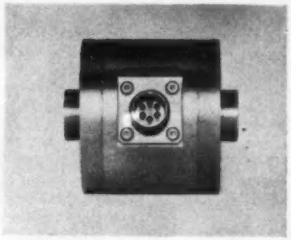


spring-loaded lid is closed, the basket rotates at a speed of 420 rpm, the resulting centrifugal force displacing the surplus oil. At the same time, an electrical heating element follows up with hot air to reduce the viscosity of the remaining oil on the swarf or components, the hot air being blown into the basket by an impeller. This double action ensures that the maximum possible amount of oil is reclaimed. The total time taken to separate the oil, filter it through a sieve, and pass it into a container ready for immediate re-use is only from 2 to 3 min. To ensure complete safety in operation the machine cannot be operated unless the lid is closed, and an electromagnetic brake stops all rotational movement as soon as the lid is lifted even a fraction of an inch. A special plunger button is also incorporated to override any other action in case of emergency.

Low-Differential-Pressure Transducers for High Line Pressures

Designed for the measurement of small bidirectional differential pressures at high line pressures, and particularly suitable for orifice-plate flowmeter applications, the new Type 4-351 strain-gauge pressure transducer introduced by the Transducer Division of the Consolidated Electrodynamics Corporation, of Pasadena, Cal., a subsidiary of the Bell & Howell Co., combines high performance characteristics with small size. Measuring only $2\frac{1}{4}$ in. in diameter by $2\frac{1}{4}$ in. in length, the transducer has a line-pressure rating of 5000 psi with less than 1% full-range shift from zero to 5000 psi, and can withstand 8000 psi without damage. The differential-pressure range is from ± 15 psi to ± 100 psi, and the unit will not deviate from specifications after the application of a differential pressure up to ten times the rated pressure.

The combined effects of linearity and hysteresis do not exceed 0·75% of the full-range output. The operable temperature range is from $-70°F$ to $+300°F$, and the compensated temperature range is from $-65°F$ to $+250°F$, with a thermal sensitivity and zero shift over the compensated temperature range within 0·01% of the full range per °F. The transducer is constructed in such a way that both active and reference pressure-ports can tolerate fluids compatible with Type-347 stainless steel.



Spreader Nozzle for Metal-Spraying Pistols

The use of metal-spraying pistols having a high throughput of metal creates new problems in spraying techniques. Indeed, pistols now available are capable of spraying zinc at the rate of 60 lb per hour and more, and aluminium at equivalent coverage rates, and it is of great importance with such high rates of delivery that the metal is applied with the utmost economy. For this reason, an auxiliary spreader nozzle has been produced by Metallisation Ltd., of Dudley, Worcs., for attachment to their Mark 33 metal-spraying pistol, and is capable of spreading the spray stream from a wire of $\frac{3}{16}$ in. diameter to an effective width of 3 in. at normal spraying distances.

Considered to represent a major step in the advancement of the use of pistols of higher output, the nozzle has been subjected to extended tests and has proved to be of definite advantage when coating large surface areas. The attachment adds very little weight to the pistol and can be fitted in a few minutes. A special feature is that it can be switched on and off independently of the pistol, this being effected by means of a small tap located at the base of the pistol.

The Present Status of Fuel Cells and Batteries

(Concluded from page 79)

solutions to ferric sulphate and hydrogen. The electrochemical cell has a hydrogen anode and a ferric sulphate cathode. Another system uses alpha-decay polonium-210 to decompose water into hydrogen and hydrogen peroxide, which is then catalytically decomposed into water and oxygen. The electrochemical cell in this case would be a hydrogen-oxygen cell.

Conclusions

Insofar as the present status of fuel cells and batteries is concerned, it is concluded that the use of electrochemical cells as efficient energy sources is limited to primary cells. With the possible exception of the hydrogen-oxygen system, fuel cells still require considerable development before they are ready for use as energy sources. The use of electrochemical cells as secondary power sources is limited to the well-known secondary battery.

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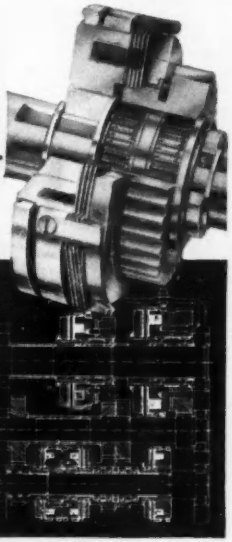

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Maximum grinding length	1000 mm
Maximum grinding width	270 mm
Width of clamping table	250 mm
Maximum height of work-piece	370 mm
Rapid replacement of head-remotely controlled	350 mm
Wheel diameter ...	275 mm
Automatic vertical feed	from 0.01 to 0.05 mm

TECHNICAL DATA

Wheel speed	1400 rpm
Adjustable speed of table	from 1 to 20 strokes per min
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Wheel rotation (1400 rpm)	8 kW
Hydraulic unit ...	2.5 kW
Rapid displacement ...	0.3 kW
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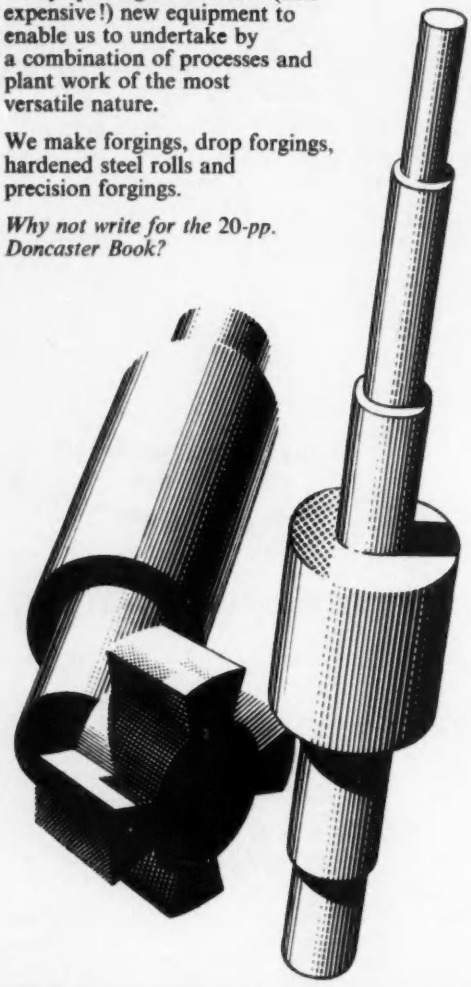

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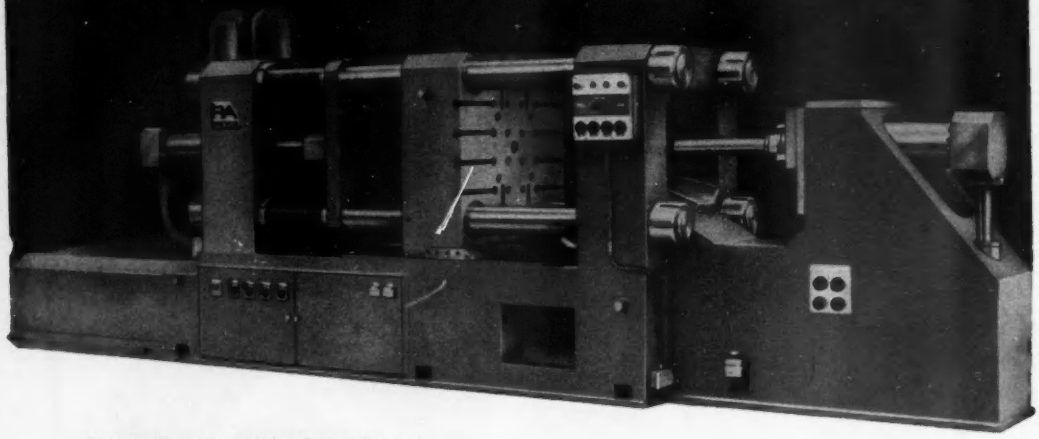

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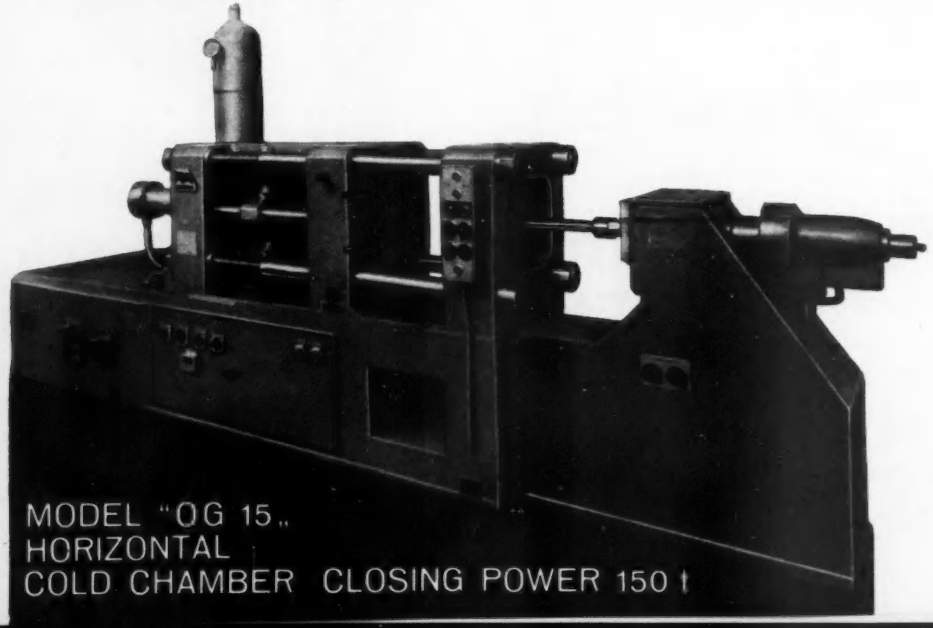

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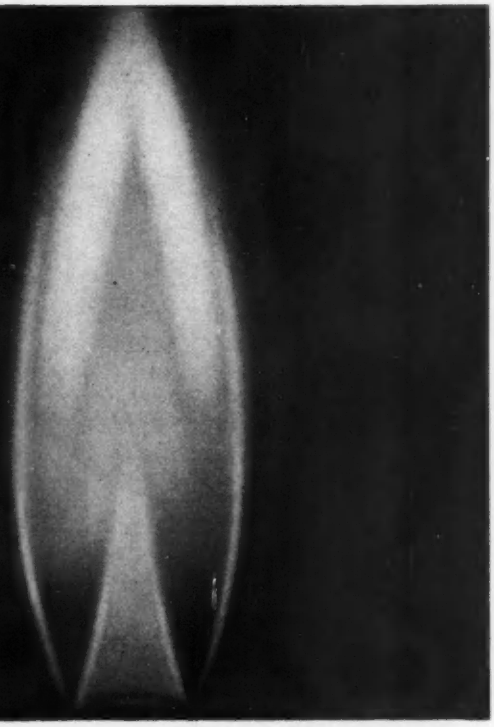

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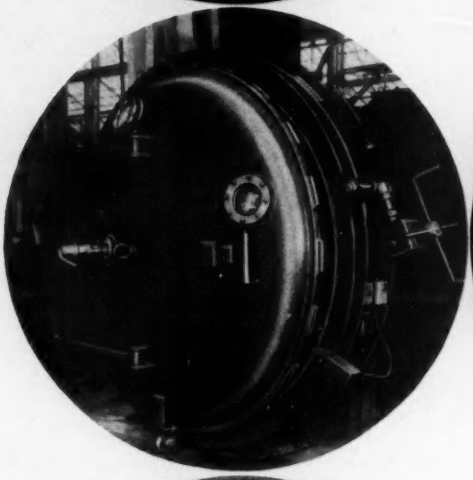

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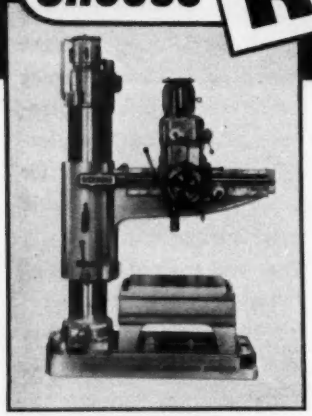

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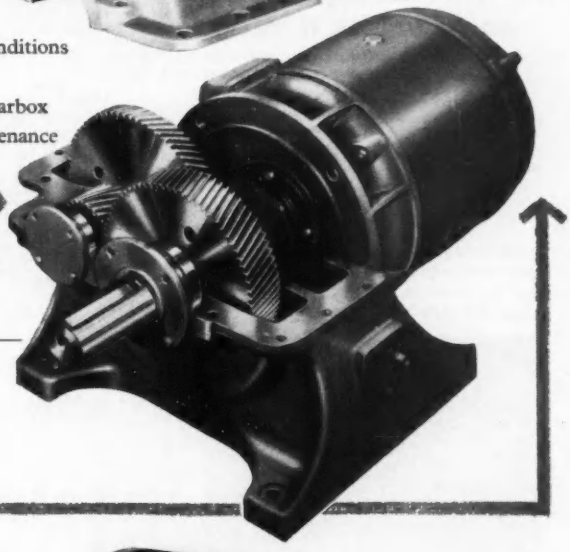

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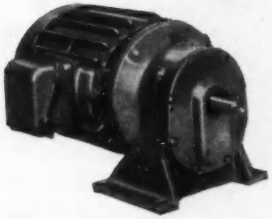

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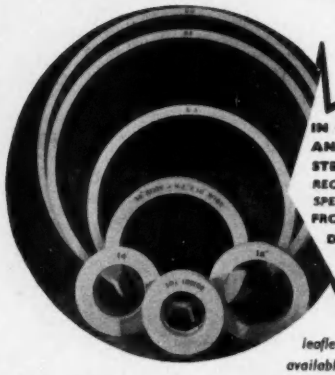

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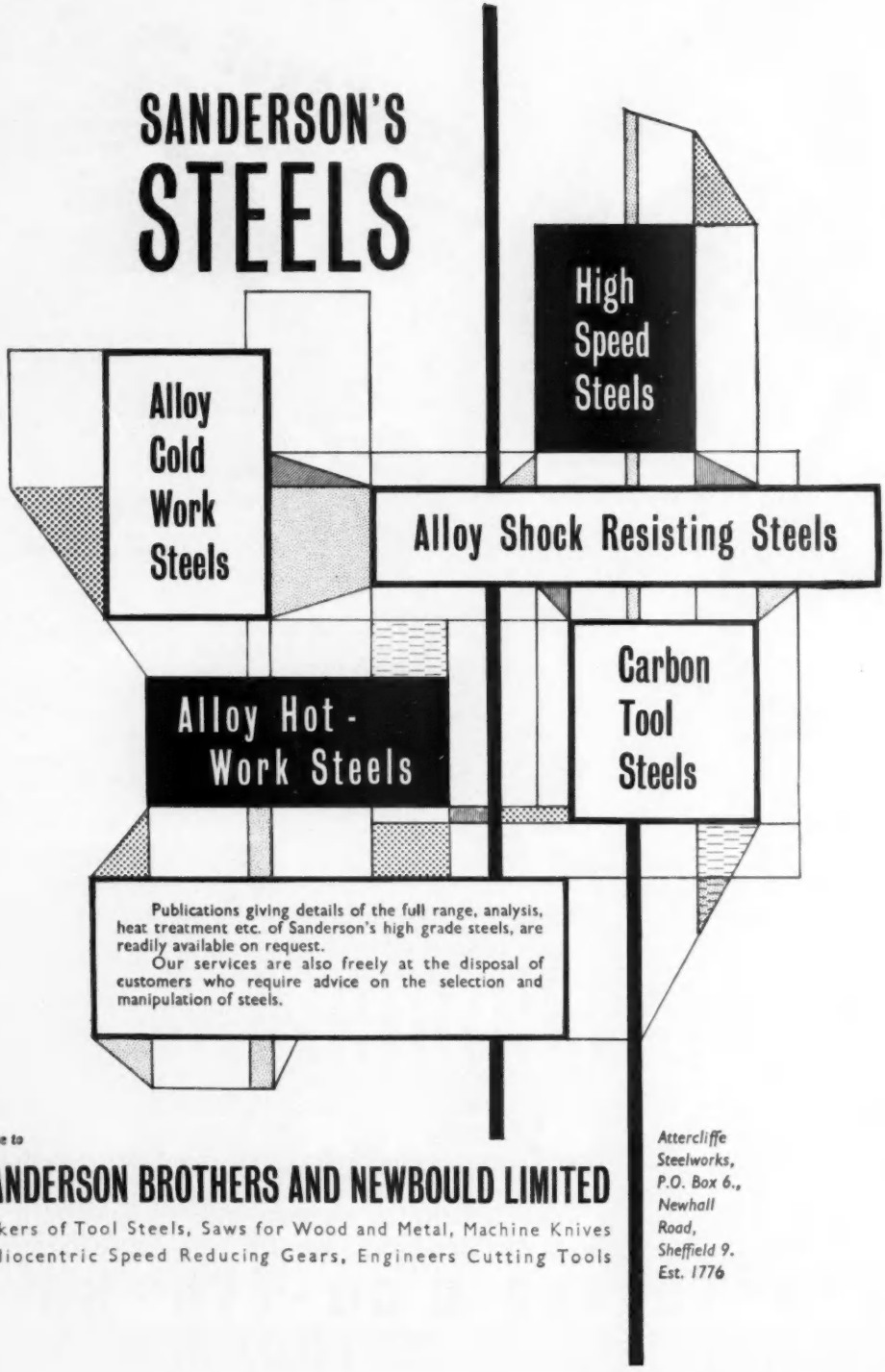

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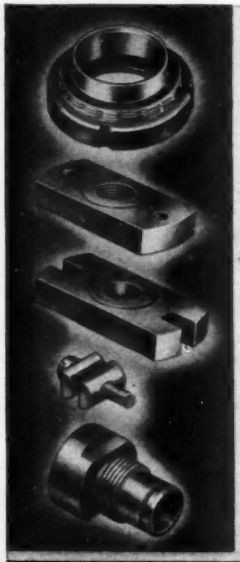

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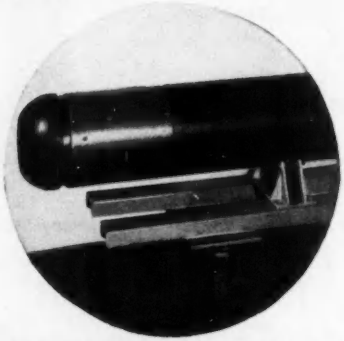

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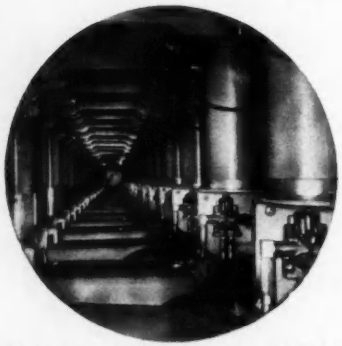

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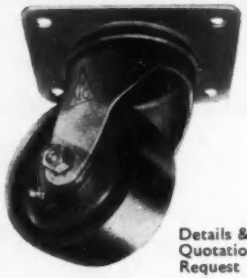

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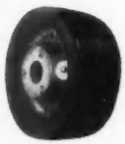

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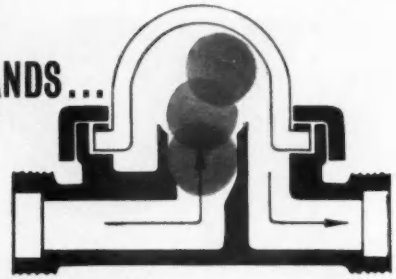

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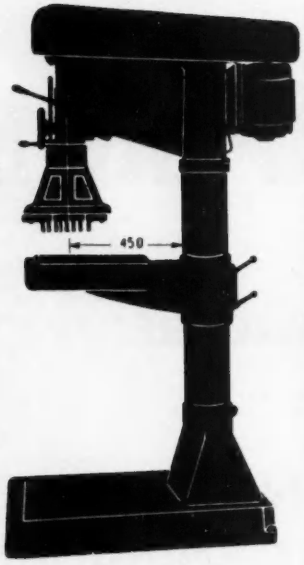

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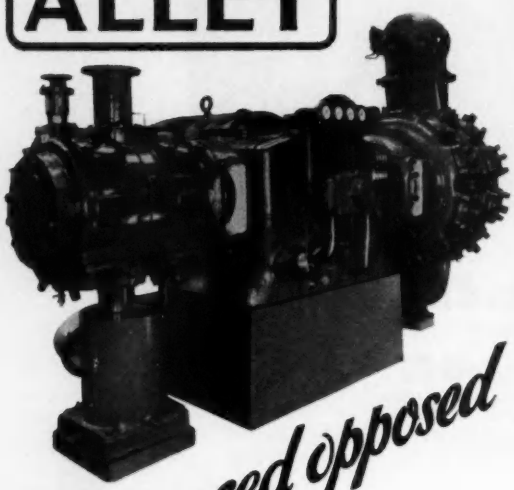

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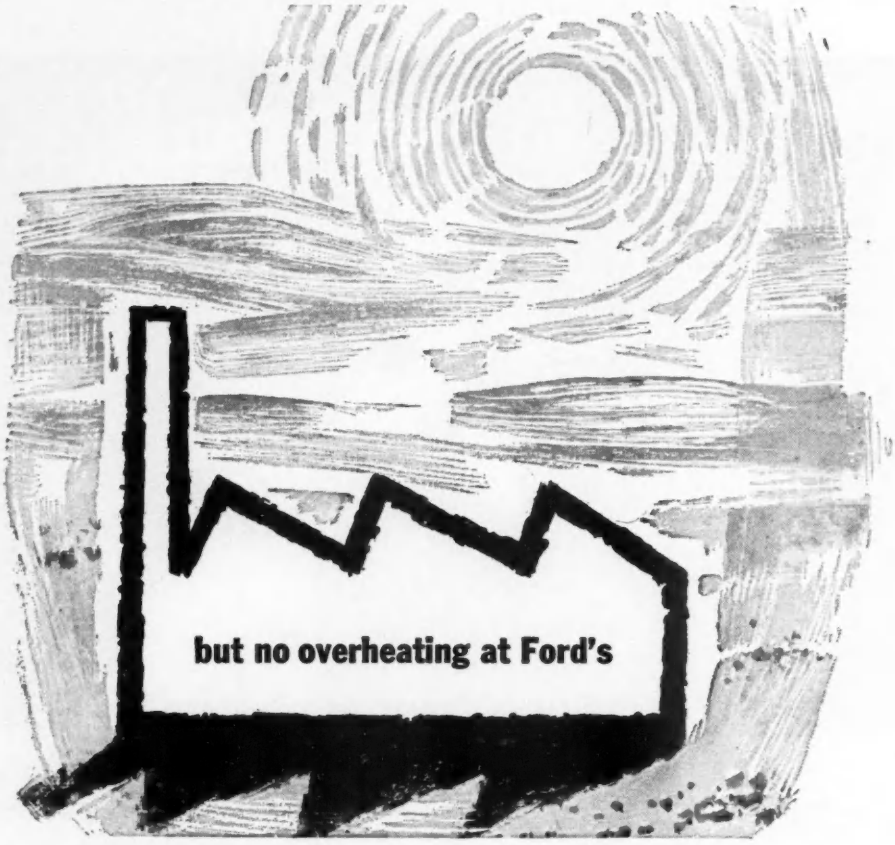

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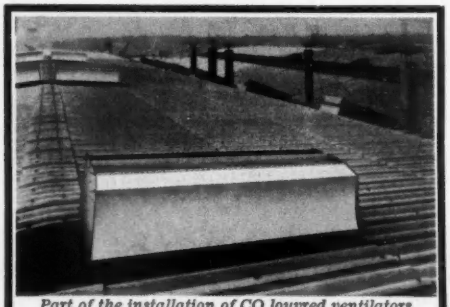

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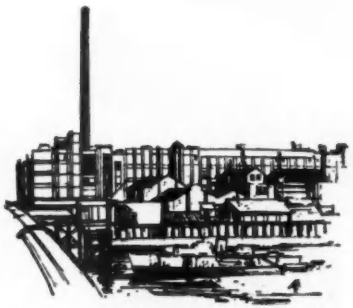

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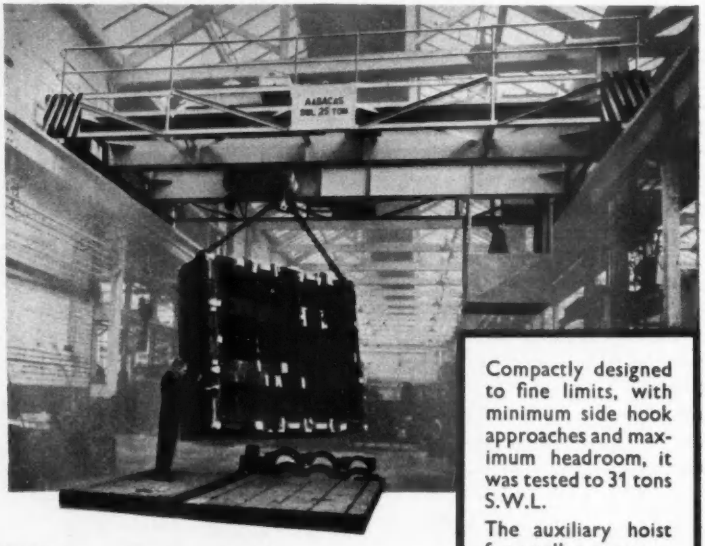

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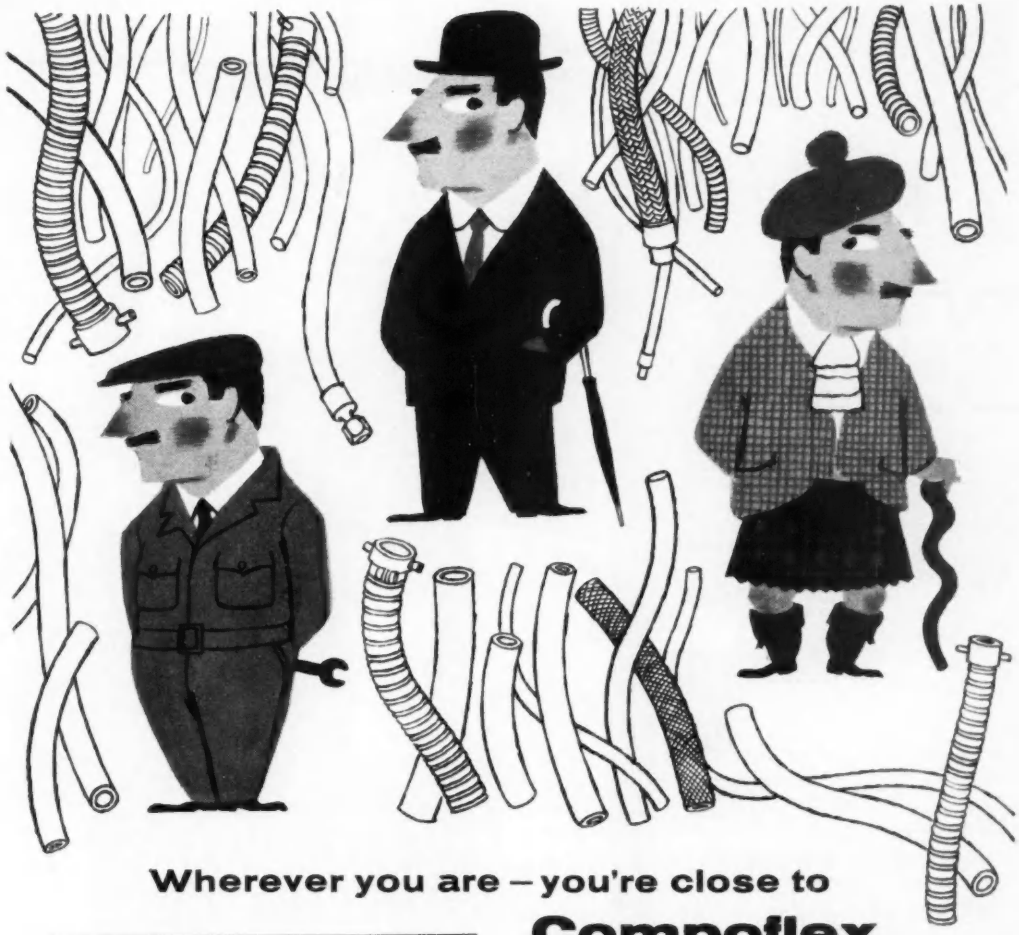

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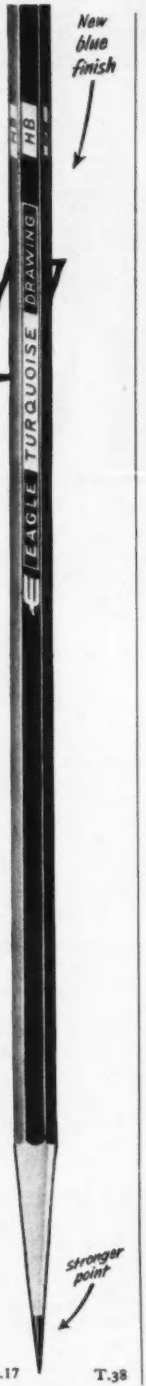

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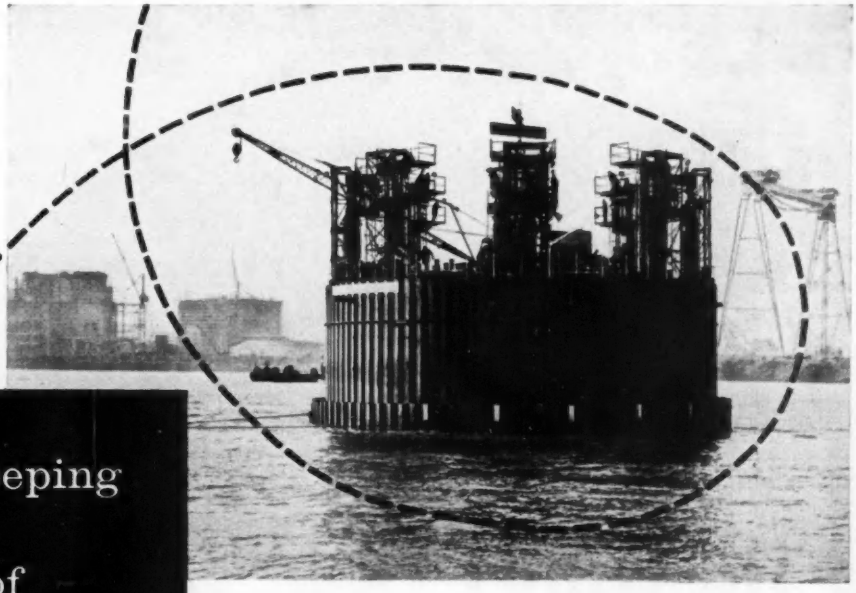

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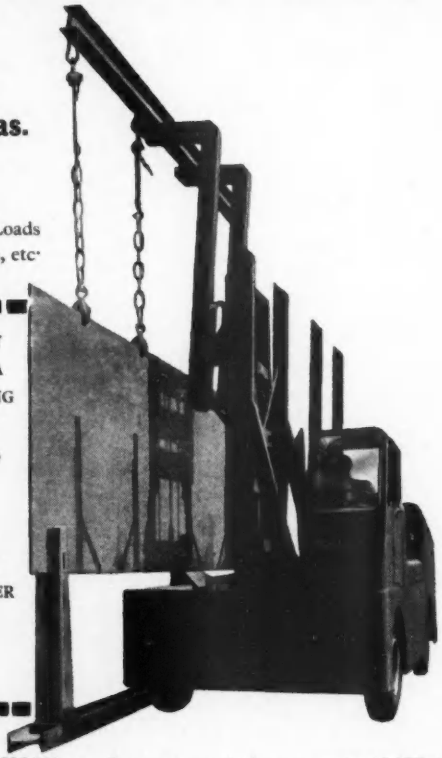

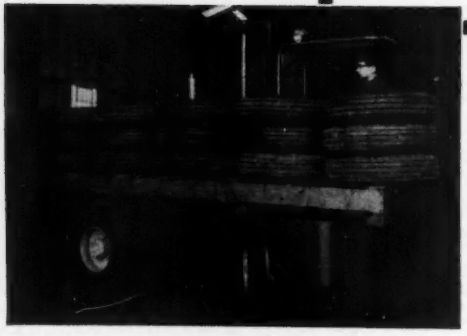

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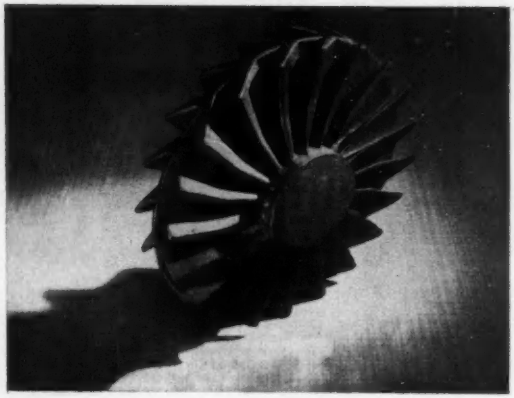

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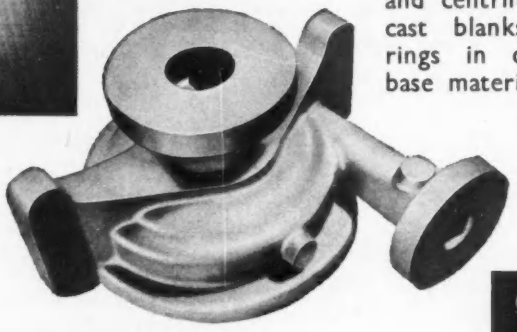

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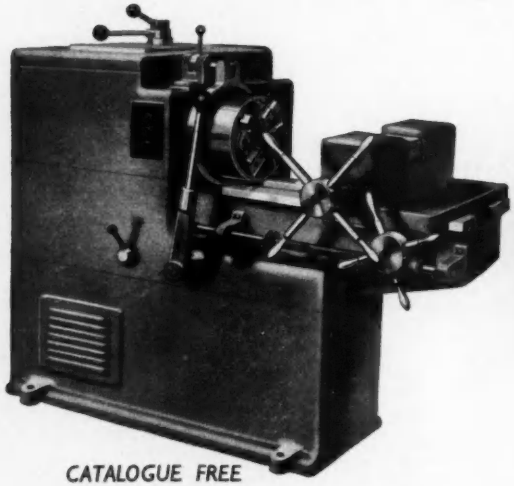

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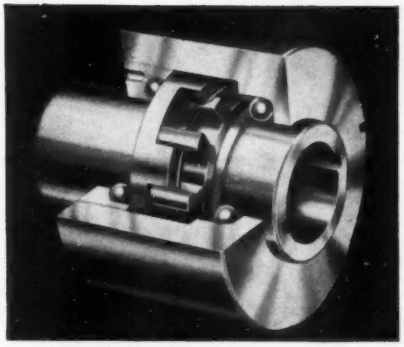

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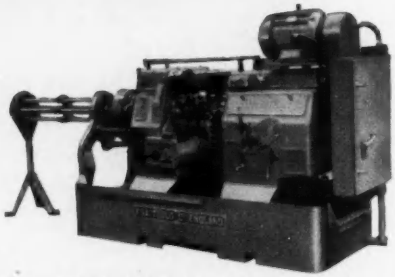

B.S.A. ACME-GRIDLEY ⅜" six-spindle automatic bar machine. Designed for high spindle speeds and fast cycle times combined with accuracy and good surface finish. Machine has two position feeding and stock can be fed during index. The main toolslide is provided with end adjustment to assist setting up for components of similar design but of varying length. Collet capacity ⅜" dia. Length fed and turned 4". Speeds 4,340 to 321 r.p.m. Motor 15 h.p.

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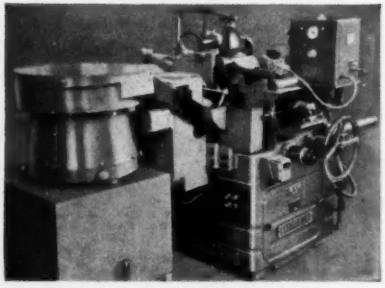

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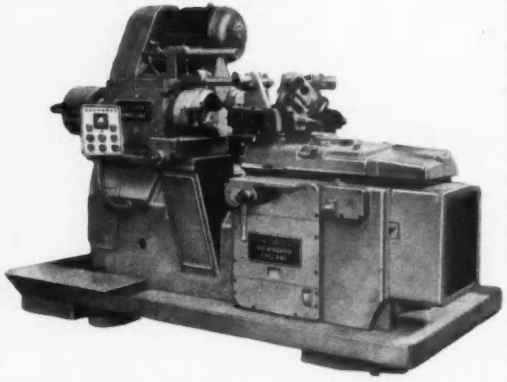
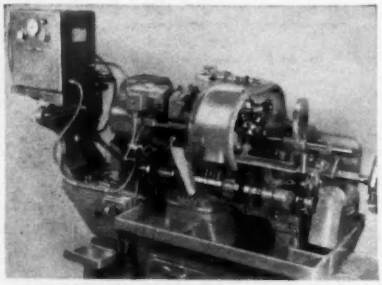


B.S.A. No. 95 All-Electric single-spindle automatic chucking machine with "DISCOTROL" programme control unit. (Complete machining programme for a component recorded on a master disc). Immediate changeover effected by substituting a new programme disc and appropriate tooling. Re-setting of machine speeds and feeds eliminated. Highly sensitive overload device protects tooling. Five-face turret. Swing over cross slides 10¾" (maximum swing 12½"). Stroke: of cross slides 4", of turret 5¾". Thirty spindle speeds: 40 to 834 or 60 to 1220 r.p.m.



B.S.A. No. 48 single-spindle automatic screw machine arranged for automatic inspection of 0.0150" hole through component. Obstruction to an air blast through the hole causes a back pressure to be fed to a control which stops the machine.

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